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COLLECTED PAPERS

of

Edmund Otis Hovey

Volume 1
(1896-1922)

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Bulletin of the Museum of Comparative Zoölogy
AT HARVARD COLLEGE.
VOL. XXVIII. No. 3.
(GEOLOGICAL SERIES VOL. III.)

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Based upon a Collection made for ALEXANDER AGASSIZ.

BY EDMUND OTIS HOVEY.

UNIVERSITY OF CALIFORNIA
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No. 3. — *Notes on the Artesian Well Sunk at Key West, Florida, in* 1895. By Edmund Otis Hovey.

In 1895 an Artesian well was sunk at Key West, Florida, to the depth of 2,000 feet. Samples of the borings were taken every 25 feet from the surface to the bottom, and through the kindness of Mr. Alexander Agassiz a set of these samples was placed in my hands for microscopic examination. The petrography of the material passed through is simple. It is all an almost perfectly pure lime-rock, and is a typical oölite at the surface and at 25 feet below. Beneath that depth most of the samples indicate a fine or coarse, more or less loosely compacted sand-rock, relieved somewhat by beds or masses of compact limestone or porous rock. Small bits of oölite, or loose ovules, are present in about half of the samples, indicating a shallow water origin for much of the material. The most solid rock of all passed through seems to come from the depth of 50 to 175 feet from the surface, inclusive.

Perhaps the most peculiar petrographic feature is the presence in all the samples except three (25, 50, 1,375 feet) of a small amount of quartz. This varies from the merest trace up to a very noticeable proportion, and is sometimes visible under a one-inch hand lens. About two grams of each sample was carefully dissolved in hydrochloric acid, and the residue washed and examined under a compound microscope. This residue consisted mostly of a very fine-grained angular sand, having the lustre and fracture of quartz, and scratching glass with ease. Some of the grains suggested the hexagonal outlines and pyramidal termination of crystals, but none was definitely made out. The particles were perfectly limpid and showed no effects of abrasion. With this angular sand were sometimes associated a few well rounded grains of clear quartz of much larger size. Frequently the rounded grains were too coarse to pass through a No. 40 mesh sieve, but this was never the case with the angular material. It seems probable that the fine grained, angular quartz is of secondary origin by infiltration of siliceous waters. That the waters percolating through the rock strata of Florida carry silica in solution, is clearly indicated by the chalcedonized Miocene

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corals from near Tampa, on the west side of the peninsula. The rounded grains, which are much fewer in number than the others, are evidently transported particles and must have come from a distance, since such quartz is not indigenous to any rocks in the vicinity of Key West.

The angular quartz sand was present in largest amount at the following depths: 250 to 325 feet inclusive, 400 and 425 feet, 800 feet, and 1,250 feet. The least was seen at the surface, at 25 and 50 feet (none), 100 feet, 150 feet, 725 feet, 775 feet, 850 to 1,225 feet inclusive, 1,300 feet, 1,325 feet, 1,375 feet (none ?), and below this there is only a trace in each sample.

With almost all the samples a flocculent precipitate settled out of the HCl solution after a time. This varied in color from a very light gray through brown to a greenish black. The nature of this precipitate was not determined.

The surface oölite, though friable, was sufficiently compact to yield a thin section. The nuclei of almost all the ovules are rounded or subangular calcareous grains. One ovule was observed the nucleus of which was a grain of quartz. The matrix of the oölite is very finely divided soft rock, composed of entirely unrecognizable material as far as any organic remains were concerned. The surface rock, in fact, and that from 25 feet as well, seem to be entirely devoid of determinable organic fragments. Small lumps of oölite or loose ovules were noted in about half of the samples scattered along from top to bottom. The upper half of the section is more oölitic than the lower, and the upper 500 feet more than any other portion. In appearance the ovules differ from ordinary rounded grains of sand in being more regular in outline and in having the exterior more highly polished. Many of these highly polished, regular ovoids were cracked open with a light blow of a hammer, or by pressure on a glass plate, thus revealing the concentric shells characteristic of true oölitic structure. To the present writer it seems important to confine the term oölite to rocks composed of these concentrically built spherules embedded in a matrix, and not to extend it as some writers are inclined to do to rocks made up merely of well rounded fragments embedded in a more finely comminuted matrix.

Organic remains which retain sufficient character for one to refer them even to their class are not numerous except in a few of the samples, and three of them (surface, 25 feet, and 550 feet) showed no determinable fragments. Foraminifera are abundant at 50 feet from the surface, and sparingly present at 75, 325, 400, 575, 625, and 675 feet. At 725 feet they begin to abound again, and are either relatively or absolutely numerous in nearly every sample from that point to the bottom, though they are few in number at 750, 1,075, 1,225, 1,350, 1,450, 1,950, and 1,975 feet, and seem to be lacking from the samples from 775 and 875 feet below the surface. The samples from 1,625, 1,650, and 1,775 feet are especially rich in these organisms. Foraminifera of the genus *Orbitoides* seem first to appear in abundance at 900 feet from the surface. From this depth down to 1,875 feet, apparently the same species of *Orbitoides* are more or less abundant. At 1,375 feet a very steeply conical *Textularia* appears, and together with a more obtuse form is persistent to the bottom, sometimes even outnumbering the *Orbitoides*. The largest *Orbitoides* were from the depths of 1,375 and 1,400 feet and measured 3.5 and 4 mm. across.

Bits of coral are present in small numbers in about half the samples, but are not numerous enough at any depth to warrant calling the sample a "coral sand," though of course many of the undeterminable fragments may have been derived from corals. Taken as a whole, there are more bits of lamellibranch shells and casts of the interior than any thing else in the referable fragments; next to these in point of numbers come foraminifera; then follow echinoderms, corals, bryozoa, and gastropods. Below the depth of 1,425 feet foraminifera greatly predominate in the meagre recognizable remains in many of the samples. Besides the organisms just mentioned there were recognized occasionally *Dentalium*, *Cæcum*, tubes of *Spirorbis* and other annelids, spicules of *Gorgonia* and bits of what seemed to be nullipores. At 425 feet a single brachiopod (*Cistella ?*) was noted. At 300, 500, and 525 feet from the surface the thin sections showed a network of tubes reminding one strongly of the Palæozoic genus *Stromatopora*. These are referred doubtfully to the nullipores. With the exception of a few of the lamellibranchs and some of the echinoderms, minute animals are indicated by the remains. In a few cases with the lamellibranchs and the gastropods the genus and even the species could probably be determined from the fragments, and all the foraminifera could be determined or described, but the echini and corals are entirely undeterminable, and the other organisms are probably so. Many of the samples look very much like the calcareous sand forming the beach two or three miles west of Nassau, New Providence, and elsewhere in the Bahamas, judging from specimens of such sand kindly furnished the writer by Prof. R. P. Whitfield.

A condensation of the detailed record of the well as obtained from the study of the samples is as follows: —

SURFACE and 25 feet, a yellowish white, friable oölite destitute of determinable organic fragments. There is a mere trace of the angular quartz sand at the surface, but apparently none from 25 feet.

50 to 175 feet, a white, yellowish white, or very light gray, more or less compact limestone with oölitic lumps in it. Recognizable remains are mostly lamellibranchs, but the 50 foot sample is also foraminiferal. Quartz sand is lacking in the 50 foot sample, but is present in varying small amounts in the others.

200 feet. — A fine white sand-rock partly compacted and almost destitute of determinable fragments. Contains a small amount of the quartz sand.

225 to 275 feet. — A porous, white, soft, somewhat oölitic and sandy rock containing some bits of lamellibranchs, but almost nothing else recognizable. The quartz sand contains the relatively large rounded grains already mentioned. There is a comparatively large amount of it (the quartz sand) in the samples from 250 and 275 feet.

300 to 375 feet. — White, more or less solid sand-rock containing a few ovules and a little oölite and some masses of dense limestone. Very few determinable organic remains are present; among these, indications of echini are relatively numerous at 325 feet, and of lamellibranchs at 375 feet. A comparatively large amount of the angular quartz sand was observed at 300 and 325 feet, and a small amount at the other two depths.

400 to 675 feet. — A decidedly gray sand-rock, presenting a marked contrast to that above, soft and friable, but containing hard, dense, light gray limestone at 500 feet, and rather hard, porous, almost white rock, with granular calcite at 525 feet. Color seems darkest in the samples from 400 to 475 feet. The quartz sand, which is present in varying amounts, shows in some of the samples a relatively large number of the coarse rounded grains. There is a great dearth of recognizable fragments throughout this lot, and at 550 feet there seem to be none. Of the few organic remains that can be determined lamellibranchs appear to be the most numerous. A single minute brachiopod was found at 425 feet, concerning which Prof. W. H. Dall writes me: "It is either the cistella stage of a large species, or a small species of *Cistella*. I am inclined to believe it the young of a larger species."

700 to 1,075 feet. — A sand-rock varying in color from a yellowish white in the upper portions to a very light yellowish brown in the lower. The texture of the rock varies somewhat, also, being more of shell-rock at 725 feet, and a rather hard, porous rock from 750 feet to

825 feet. The remainder is more sandy, with well rounded grains, but contains some angular fragments of amorphous rock (e. g., 975 feet). All is more or less oölitic. The quartz sand is present only as a trace, and sometimes (975 and 1,000 feet) is scarcely perceptible. Most of the samples from these depths are notably fossiliferous, foraminifera and lamellibranchs predominating. From 900 feet down bits of madrepore corals were noted in the samples, and such fragments were rather numerous at 1,000 feet.

1,100 to 1,175 feet.—Light gray limestone, partly dense and partly porous in texture, containing only a slight trace of the quartz sand. Somewhat oölitic at 1,175 feet. Foraminifera abound, though they are somewhat less numerous in the lower than in the upper half of this set. Bits of coral, also, are more numerous in the upper half than in the lower. The fragments in the sample from 1,125 feet indicate the presence of comparatively large lamellibranchs. Remains (casts) of gastropods are more numerous at 1,150 feet and 1,175 feet than in most of the samples.

1,200 to 1,350 feet.—A gray sand-rock with the 1,200 foot sample a transition to that above, but in all the set there are many angular bits of dense and porous limestone among the rounded grains indicating the sand-rock. The quartz sand is present in all, but in the sample from 1,250 feet there is more than in any other for 350 feet above it and all the rest of the distance to the bottom of the boring. Fossils are rather scarce in this set, even foraminifera being numerous only in the three samples 1,275, 1,300, and 1,325 feet. Coral fragments come next to the foraminifera in abundance, but are very few in 1,300 to 1,350 feet. From 1,250 to 1,350 feet the rock is somewhat oölitic.

1,375 to 1,450 feet.—A yellowish gray sand-rock containing some porous limestone (much at 1,400 feet) and a little dense rock, but becoming a fine, closely compacted sand at 1,450 feet. *Textularias* of at least two species appear at 1,375 feet, and are persistent in most of the samples from this point to the bottom of the boring and outnumber the *Orbitoides* at most depths. Aside from the foraminifera very little is determinable, most of each sample except that from 1,400 feet being so finely comminuted as to pass through the No. 40 mesh sieve. Of quartz sand there seems to be none at 1,375 feet, and only a trace at the other depths. Ovules and bits of oölite are not numerous. There is some iron stain at 1,450 feet.

1,475 to 1,975 feet.—Sand-rock varying somewhat from one depth to another in color, compactness, and amount of contained dense and porous limestone. Rounded grains are evident in the samples, and ovules and oölite occur at some depths. As to color, 1,475 feet is a decided gray, presenting a readily recognized contrast to 1,450 feet; from 1,500 feet to 1,775 feet the material is pretty uniform in color, and would be described as being light brownish gray, but dark brown spots due to iron oxide occur at 1,600 feet; 1,800 feet is light brown with many white particles (fossils, etc.); from 1,825 feet to 1,975 feet the samples are light brownish gray with a yellowish cast, or are light yellowish brown and contain more or less of the white particles. In all the samples there is a trace, or a little more, of the fine angular quartz sand, together with an occasional larger rounded grain. Determinable fragments of organisms are few in all the samples and almost absent in some. Foraminifera are by far the most abundant recognizable fossils, and they form a considerable percentage of the samples from 1,625 feet, 1,650 feet, and 1,775 feet. *Textularia* is the most numerously represented genus, with *Orbitoides* next. *Amphistegina*, *Cristellaria*, *Orbitolites*, and other genera, are also easily to be found. Other classes of organisms are not common, even lamellibranchs not being numerous except at 1,600 feet. Corals are not abundant in any of the set, and seem to be entirely lacking from many of them.

2,000 feet. — At this depth the rock loses its yellowish cast and becomes a light brownish gray, contrasting somewhat with 1,975 feet. The rock seems to have been a rather solid limestone with porous portions. It was very fossiliferous, foraminifera being especially abundant, though other classes are well represented. The obtusely and the sharply conical *Textularias* are the most numerous and *Orbitoides* seems to be absent.

Although the genus *Orbitoides* does not seem to be represented in the samples from depths above 900 feet from the surface, except sparingly at 800–850 feet, there seems to be no particular change in the rock until after 700 feet has been reached, and there is a marked transition between the sample from that depth and the one next above (675 feet). On account of these facts I am inclined to place the approximate upper limit of the Vicksburg beds of the Eocene in this well at 700 feet below the surface of the ground. The lower limit of the Vicksburg is not easily made out. *Orbitoides* seems to be the predominating foraminifer down to 1,450 feet inclusive. Between this depth and the next (1,475 feet) there is a decided change in color, and while *Orbitoides* does not disappear entirely at once, the two conical forms referred to *Textularia* are much more numerous. Below 1,875 feet *Orbitoides* seems to be lacking.

Above 700 feet the material was so comminuted, probably by the drill, that it seems impracticable to differentiate the Miocene and Pliocene beds. The surface oölite ceases between the depths of 25 and 50 feet, which may indicate that the top of the Tertiary is there. Furthermore, it seems that the marked change in the appearance of the beds between 375 and 400 feet from the surface must be of some significance.

The following notes on the samples of the borings from the Artesian well at Key West will give an idea of the condition and composition of the material examined.

SURFACE. — Color yellowish white. The surface rock consists of an oölitic limestone which pulverizes with comparative ease between the fingers. The nuclei of the ovules are for the most part rounded or subangular calcareous grains, but one ovule was observed which was built up around a grain of quartz. The matrix consists of minutely comminuted stuff. No fragments of either shells or coral were observed. The rock left the merest trace of quartz sand behind on treatment with HCl, like that which is fully described under the material from 250 feet and deeper.

25 feet. — Color yellowish white. Oölite; like the above, apparently, though the sample consisted of nothing but the ovules. Not even a trace of the quartz sand noted. After a time a flocculent brownish white precipitate settled out of the HCl solution. A flocculent precipitate like this, but varying in color to a greenish black, was obtained with almost all the samples. See Analysis, p. 85.

50 feet. — Color white with yellowish and brownish portions. A compact, somewhat sparry limestone filled with fragments of foraminifera, corals, remains of echini, lamellibranchs, gastropods, etc. Crystals of calcite are present, as is true of many of the other samples. The rock contains vast numbers of foraminifera and other calcareous micro-organisms. No quartz sand, apparently. The rock is oölitic, but is not friable like the two preceding. It is mainly a shell limestone with much oölite and foraminiferal rock.

75 feet. — Color gray-white. A compact limestone containing pieces of coral and porous lumps. Under the microscope the rock is seen to contain fragments of shells and coral in a fine granular base in which are some foraminifera. There is a very small amount of limpid quartz sand present and a heavy gray-white flocculent precipitate settles out from the HCl solution after a little time.

100 feet. — Color white. Compact limestone containing abundant remains of corals and shells, pectinoids, and other lamellibranchs. Some of the shell fragments are in a matrix of oölite. Very, very small amount of quartz sand. Much of the flocculent precipitate in HCl. The lamellibranchs predominate among the determinable remains.

125 feet. — Color white with brownish white portions. The sample is of an almost pure white rock, but it contains a fragment of limestone like the preceding, cracks in which have been filled with secondary calcite. It is a very porous rock for the most part. There are a few casts (or imprints) of parts of corals present. Consists of fragments of shells (lamellibranchs) and many ovules in a matrix of amorphous or unrecognizable material. Sometimes the shells have leached out leaving the rock porous. Part of the sample is a true oölite, some of which is friable and some has been cemented by calcite to form a firm rock. The sample contains internal casts of lamellibranchs and fragments of their shells. A very small amount of limpid quartz sand is present.

150 feet. — Color yellowish white. A trace of quartz sand is left on dissolving the rock in HCl. The rock seems to have been a hard, compact limestone. Observed fragments of shells and internal casts of lamellibranchs and a few pieces of coral; many rounded grains, but very little true oölite. Most of the recognizable organic remains are of lamellibranchs. There are many facetted fragments which seem not to have been made by the drill, but to be the remains of the internal pillars of sea-urchin tests. There are many angular bits of stone which is as dense and crystalline as marble.

175 feet. — Color white. A limestone like the last, except that it seems as if a larger proportion of it were porous and a smaller proportion determinable. A small amount of quartz sand is present. Lamellibranchs predominate among the remains that are determinable.

200 feet. — Color yellowish with many pure white particles (bleached organisms). This sample consists almost entirely of a fine uncompacted calcareous sand in which there is a very small amount of limpid quartz sand. The particles of the sand have been weakly cemented in places. A few chips indicate the presence of some compact rock. The grains are rounded and subangular. Ovules were noted but are scarce. The fragments were almost all undeterminable, but in the small portion of the sample which failed to pass through a No. 40 mesh sieve there were a few pieces of madrepore corals, some indications of echini, fragments of both branching and incrusting bryozoa, bits of lamellibranch shells, and casts of minute gastropods.

225 feet. — Color white with very slight yellowish tinge. Sample contains a small amount of fine angular quartz sand; coarser grains of quarts were rounded. Rock was a rather porous limestone with areas of granular calcite. Partly oölitic. There were but few determinable organic remains in the sample. A very few bits of coral, spines of echini, and fragments of branching bryozoa were noted. Many fragments of lamellibranch shells and casts (*Arca? Pecten?* etc.), and a very few internal casts of minute gastropods.

250 feet. — Color white. Sample consists of rounded and subangular grains. Rock was a soft, porous, and granular limestone. A considerable percentage of very fine-grained limpid quartz sand is present, the particles of which are angular or but slightly rounded. No definitely terminated crystals were observed, though some of the surfaces suggested the rhombohedral planes in shape and position. By far the largest part of this quartz sand is very minute in size,

but an occasional particle of larger size, even up to a millimeter in diameter, occurs. These larger grains are well rounded and somewhat rough on the exterior, rendering them less transparent. The quartz particles are recognizable with an ordinary lens. No recognizable fragments of organisms were noted, except a very few of lamellibranch shells. A very little oölitic material was noted.

275 feet. — Color white. This rock is more compact than the last, and may be described as a rather solid lime sandstone. (I use this term as meaning a lime rock in which the individual grains of calcareous sand are readily discernible. It would bear somewhat the same relation to compact limestone that ordinary siliceous sandstone does to quartzite.) Some fragments in the sample are of compact limestone. The amount of limpid quartz sand is larger than in the last sample. Recognizable organic remains are very scarce. Noted, however, one or two pieces of coral, a few bits of bryozoa, and a good many more of lamellibranch shells and casts.

300 feet. — Color white. This is a sand-rock containing some portions of dense limestone and a small percentage of oölite. Very few determinable organic remains were observed. Noted a few bits of millepores, a few fragments of bryozoa, coral doubtful, pieces of lamellibranch shells of several genera, and a very few internal casts of minute gastropods. A very noticeable proportion of the limpid quartz sand is present. Some measurements of grains gave diameters of 0.12 mm. and 0.1 mm. as average, with an occasional larger particle, one of which was 0.55 mm. across. The mass of the rock is made up of white calcareous sand cemented together too firmly to be crushed between the fingers. There are a few ovules. These are easily distinguished by their regular form and smooth exterior. A thin section made from a hard lump shows a structure comparable with that of a Palæozoic *Stromatopora*. The cells are too irregular to be those of a millepore and the reticulate structure may be due to anchylosed branches of a nullipore. (A similar organism from 500 feet shows that these apparently solid branches are tubes.)

325 feet. — Color a yellowish gray-white. Limpid quartz sand, as in last three samples. The sample is made up almost wholly of fine, angular calcareous sand, but there are some lumps. It was a sand-rock. Ovules are scarce but present. Very few fragments are determinable. Some are apparently nullipores. Spines and plates of echinoid tests are relatively numerous. Branching bryozoa not rare. Some few bits of lamellibranch shells. Very, very few remains (casts) of gastropods, one of which is a comparatively large trochoid shell. Annelid tubes in groups and singly. Found several (half a dozen or so) foraminifera. The single annelid tubes are strongly curved and may be *Spirorbis*.

350 feet. — Color a yellowish gray-white. Small quantity of the quartz sand present. One fragment, at least, seems to show the terminal crystal planes. A few considerable fragments of coral are in the sample, and fragments (spines and pieces of test) of echini and lamellibranchs. One piece is apparently part of a group of annelid tubes. No ovules observed. The rock

was a comparatively coarse white sand-rock with very few determinable organic remains in it.

375 feet. — Color yellow gray-white. A sand-rock with many coarse particles in it. The fine angular quartz sand is present in very small amount, with an occasional much coarser particle which is well rounded on account of abrasion. Very, very little of the material is determinable. I noted a few small bits of coral and more fragments of lamellibranchs, three or four spines of echini, and as many pieces of annelid tubes. Some ovules are present. The coarser particles of the general sample are angular bits of dense white limestone.

400 feet. — Color a decided gray, in marked contrast with the white rock of the preceding samples. The rock was a rather loosely compacted sand-rock, containing some porous, hard, white fossiliferous portions. A few bits of oölite and some single ovules were noted, also white. The limpid angular quartz sand is present in noticeable proportion. It is very fine and uniform in grain. One foraminifer, two or three kinds of coral, some fragments of bryozoa, more lamellibranchs, part of the internal cast of a gastropod, portions of annelid tubes, and bits of nullipores (?) were observed among the meagre determinable organic remains.

425 feet. — Color decided gray. The fossils are white. The gray sand-rock which makes up more than nine tenths of the sample seems to contain very few fossils; these are mostly to be found in the hard, dense, and porous white masses which are scattered through the gray. The quartz is present in comparatively large proportion, mostly very fine grained and angular, but with an occasional more or less rounded particle. One of the last measured 1.5 × 1 mm. Determinable organic remains are scarce, as usual, and are for the most part of lamellibranchs (shells, casts, and imprints). Noted also a few bits of coral and a few fragments of echini (spines, tests, and internal facetted supporting pillars), and part of the frond of a bryozoan. Small oölite aggregates are not uncommon. A single minute brachiopod was found, concerning which Prof. W. H. Dall writes me, "It is either the cistella stage of a large species, or a small species of *Cistella*. I am inclined to believe it the young of a larger species."

450 feet. — General color and character of sample are like the last. The rock consists of loosely compacted, very fine grained calcareous sand, with occasional lumps of hard white limestone. The limpid quartz sand is present in very small amount, but with the same characteristics as before. Measurements of some of the grains were 0.1 mm., 1.5 mm., 0.09 mm., and 0.11 mm. in diameter. Angular pieces of secondary calcite as in many of the samples. Some bits of oölite observed. Internal casts of lamellibranchs rare. Fewer of the angular fragments of solid limestone present than in the last two samples, and almost nothing is determinable.

475 feet. — Color decided gray, more uniform in color and texture than the three above. This is a lime sand-rock, somewhat friable, like the last three samples, except that it contains fewer fragments of solid limestone than even

the last, and next to nothing is determinable. Small amount of the limpid quartz sand with the usual features. Fragments of a bryozoan and a very few lamellibranchs and echini noted. The sample includes lumps of firm white oölite.

500 feet. — Color decided gray, with white fossils and pearl-gray limestone. Sand-rock, rather friable but with hard lumps. Contains some fossils, which are white, and some white aggregations, as well as fragments of compact gray limestone. Occasional small lumps of white oölite are present. Quartz sand present in small amount as before. Pieces of compact gray limestone show, in the thin section, the stromatoporoid structure noted at 300 feet and doubtfully referred to a nullipore. This is made up of branching, anchylosed tubes solidified by calcite. Fragments of lamellibranchs, one of them a *Corbula*, another an *Arca* (?); spines and other parts of echini. A nearly entire spine had been perforated lengthwise by a boring lamellibranch now in it. Bits of coral are not rare. There are also a few fragments of bryozoa. Gastropod remains are very scarce. Saw part of internal cast of one minute one.

525 feet. — Color decided gray, with white lumps and yellow-white fossils. A very friable sand-rock containing masses of hard white porous rock and white fossils and calcite. Much like preceding in color, amount of quartz sand, etc. It is composed of loosely compacted, very fine calcareous sand, with few solid fragments and almost nothing recognizable. A piece of porous limestone shows moulds of lamellibranch shells, spines of echini, etc. There is also a piece showing the "stromatoporoid" structure, like those in the material from 300 feet and 500 feet. Some oölite; secondary calcite, of course. Some indications of coral.

550 feet. — Color decided gray, like 475. A very friable sand-rock, very uniform in color and texture. Almost no bits of white. The small amount of quartz sand present is relatively coarse in grain. Remarkably destitute of determinable fragments, recognized none in fact.

575 feet. — Color decided gray, like 475. A friable sand-rock like the last except that it contains some recognizable fragments. Small amount of the quartz sand present. Some ovules and an occasional small piece of oölite present. Sample mostly a very fine sand, more than two thirds of it going through a No. 40 mesh sieve. Fragments of lamellibranch shells, one minute gastropod, three or four bits of bryozoa, and one piece of coral recognized. A few foraminifera of the genus *Amphistegina* were noted.

600 feet. — Color decided gray, like 475, but lighter shade. A friable sand-rock containing much white material which is mostly crystalline limestone or granular calcite. Quartz sand in small amount as before, very fine grained, angular, no large particles. A few ovules are present and some fragments of lamellibranchs together with the facetted fragments. More than three fourths of the sample went through the sieve, much of the fine stuff being mere dust. Almost nothing determinable.

625 feet. — Color gray, like 600. A very friable sand-rock, but with less white material in it and therefore darker colored as a whole. Limpid quartz

same as last. The sample consists of uncompacted fine calcareous sand, with few large fragments in it. The facetted fragments, a few pieces of lamellibranch shells, and a branch of a calcareous alga (?) were noted. Some few ovules. Part of a spine of an echinus. The test of a foraminifer of the genus *Cristellaria* (?). Almost nothing is determinable.

650 feet. — Color gray, like 600. A very friable sand-rock, like the last. Limpid quartz is very small in amount, and seems to be of finer grain than the average. Spines of echini, lamellibranch shells, an alga (?), and pieces of oölite were noted. Almost nothing is determinable.

675 feet. — Gray, like 600, possibly a little darker. A very friable sand-rock. Quartz like the last, but with more of the larger rounded grains. Small pieces of oölite, lamellibranch shells, spines of echini, and tests of foraminifera noticed. One of the last looked like an *Orbitolites* and another like a *Clavulina*. As in the preceding five, there is a great dearth of referable fossil remains.

700 feet. — Color yellowish gray-white, very different from 675 and above. Marked change in the rock. Sample is a very fine uncompacted sand, almost all of which passed through the No. 40 mesh sieve. Amount of quartz sand has dropped off considerably. The quartz grains are more varied in size than has been usual. Fragments of lamellibranch shells and spines of echini, small pieces of oölite, and many detached ovules are present. Almost nothing is determinable. The whole sample looks like a fine beach sand.

725 feet. — Yellowish white (ecru) limestone, mostly a "shell rock." Amount of quartz reduced to a trace. Many relatively large fragments of lamellibranch shells are present, some of which are recognizable as *Pectens* or closely related shells. A very few minute gastropods. Spines of echini and pieces of their tests, many ovules and some pieces of oölite observed, bryozoa, and foraminifera (*Amphistegina ? Orbitolites ?* etc.) are numerous. A considerable proportion of the sample is of determinable fragments. A globular foraminifer appears and is relatively abundant.

750 feet. — Color yellowish white (ecru). Very small amount of quartz sand. Fragments and internal casts of lamellibranchs, — pectinoids, etc. Parts of internal casts of minute gastropods. Fragments of tests of echini. *Orbitolites* (?) and other foraminifera. Ovules but no oölite observed. Some bryozoa. A few fragments of corallines (?).

775 feet. — Color very light yellowish brown. A hard, rather porous, highly fossiliferous limestone. Trace of the quartz sand very fine. Many shells and casts of pectinoids and other (small) lamellibranchs. Small gastropods. Spines and plates of echini. Ovules present in small numbers. There are considerable fragments (⅜" × ⅜" × ¾") present, but no coral was observed. Foraminifera are very scarce, if present at all none were observed.

800 feet. — Very light yellowish brown, like the last. Amount of quartz sand small, but greater than in any of the last four samples. The rock seems to have been a rather hard, very porous limestone. Ovules rather numerous. Foraminifera (*Orbitolites ? Cristellaria ? Amphistegina ?* etc.) in numbers. A

very few discoid *Orbitoides* are present. Shells and casts of lamellibranchs numerous. Casts of gastropods. Spines and plates of echini. Some fragments of shells show the effects of boring organisms. Some bryozoa, both branching and incrusting.

825 feet. — Color very light yellowish brown. Sample is finer grained than the last. Small amount of quartz sand, one rounded particle of which measured more than .5 mm. in length. Ovules present in considerable numbers. In this and other cases the concentric structure is evident when the ovule is broken across. The rock seems to have been somewhat compacted. More secondary calcite than usual. Many shells and casts of lamellibranchs and few of gastropods. Spines of echini and the facetted fragments. Annelid? tubes. Foraminifera. Bryozoa. Some spicules of *Gorgonia*. A very few fragments of discoid *Orbitoides*.

850 feet. — Color very light yellowish brown. Sample is a fine sand, nine tenths of which passed through the No. 40 mesh sieve. Trace of the quartz sand. Foraminifera of several genera abound. Some small fragments of coral. Branching and incrusting bryozoa of several genera were observed. Many shells and casts of minute lamellibranchs. Internal casts of very small gastropods. Spicules of *Gorgonias* numerous. Ovules also frequent. Spines of echini. *Orbitoides?* very scarce, but *Cristellaria? Amphistegina? Orbitolites?* etc., numerous.

875 feet. — Color very light yellowish brown, like the last. Mere trace of the quartz sand. Sample is meagre in determinable organisms. Ovules not very numerous. Spicules of *Gorgonia*, spines of echini, and remains of lamellibranchs are present. Some pieces of brown granular calcite. *Orbitoides* not observed.

900 feet. — Color, very light yellowish brown. Trace of quartz sand as in last. A few small fragments of loosely compacted rock. Foraminifera of several genera. *Orbitoides* in numbers appear. Some small bits of madrepore and other coral. Many shells and casts of small lamellibranchs. Gastropods not definitely recognized. Fragments of tests of echini. Nullipores? Spicules of *Gorgonias*. Ovules not very numerous. Some bits of brown granular calcite.

925 feet. — Color very light yellowish brown. Many white particles. Faint trace of quartz sand. Ovules not numerous, but there are some pieces of oölite. Foraminifera abound among which *Orbitoides* are very numerous. Some few fragments of madrepore coral. Bits of echini occur, and one little fragment suggests the arm of an astrophyton. Remains of lamellibranchs are common, but those of gastropods are rare. Spicules of *Gorgonias* in numbers. Bryozoa not rare. Most of the determinable fragments are foraminifera. The whole sample looks like a moderately coarse beach sand rather than crushed rock.

950 feet. — Color light yellowish brown. Texture same as preceding. Faint trace of quartz sand. The sample is a loose fine sand in which ovules are numerous. Foraminifera (*Orbitoides*, etc.) abound. Bits of madrepore coral

not rare, — more numerous than heretofore. Remains of echini unusually scarce. Bryozoa scarce, but include branching and incrusting forms. Remains of lamellibranchs rather numerous, but few gastropods recognized. Spicules of *Gorgonias*. Proportion of recognizable remains seems rather less than in the last.

975 feet. — Color very light yellow brown. Sample shows more evidence of being comminuted rock. Quartz sand scarcely perceptible. Ovules occasional, and rounded grains very numerous. Foraminifera (*Orbitoides* and others) abundant. A few pieces of coral were noted. Bits of echini occur, and facetted fragments are numerous. Bryozoa not observed. Remains of lamellibranchs numerous, but those of gastropods scarce. Seems to have been a loosely compacted, rather coarse sand-rock.

1,000 feet. — Color light yellowish brown. Quartz sand scarcely perceptible. The sample contains a considerable proportion of coarse sand and fragments. Ovules not noted, though rounded grains are numerous. Foraminifera of several genera abundant, — *Amphistegina*, *Orbitoides*, the globular one, etc. Bits of madrepore coral frequent. Annelid tubes and *Serpula* (?) or *Vermetus* (?). Fragments of tests of echini (*Spatangus ?*). Lamellibranchs as usual, and gastropods not uncommon; of the latter, *Turritella*, *Natica ? Cæcum*, and *Dentalium* were recognized. Bryozoa present. Spicules of *Gorgonia*.

1,025 feet. — Color very light yellow-brown. Trace of quartz sand. Sample is fine calcareous sand with the coarser remains of organisms. Ovules not noted, but rounded grains are common. Foraminifera very abundant. Small bits of madrepore coral not infrequent. Both branching and incrusting bryozoa. Lamellibranch remains as usual. *Cæcum* and *Dentalium* observed, and other minute gastropods frequent.

1,050 feet. — Color very light yellow-brown. Trace of quartz sand. No ovules noted. Foraminifera form the principal constituent of the coarse part of the calcareous sand. A few pieces of coral. Bryozoa as in last. Remains of lamellibranchs common, but gastropods scarce.

1,075 feet. — Color very light yellowish brown. Trace of quartz sand stronger than in last. The sample is a very fine sand, with only a few fragments in it too coarse to go through the sieve. In the residue there were foraminifera, a few bits of coral, a single spine of an echinus, some bryozoans, and more lamellibranch remains. Ovules are present in the sample, but very scarce.

1,100 feet. — Color light brownish gray. Trace of quartz sand. The sample is a fine uncompacted calcareous sand, containing a much larger proportion of coarse particles and fragments than the last. Ovules seem to be absent. Foraminifera of several genera are numerous. Bits of madrepore corals are very numerous. Bryozoa of both branching and incrusting forms are not rare. Lamellibranch shells and casts are present in abundance, but gastropods are scarce. I noticed a few spines of echini also, and some of the facetted fragments described in the earlier part of these notes.

1,125 feet. — Color light brownish gray. Very slight trace of quartz sand.

The sample is a coarse calcareous sand (gravel it might be called) with many recognizable fragments in it, and not much of it passed through the sieve. Some pieces of compact limestone. No ovules were observed. Foraminifera not as numerous as in last. Bits of madrepores very numerous. Spines and plates of echini are scarce. Bryozoa are common, and lamellibranch remains are very abundant. A few of the fragments indicate that some of the lamellibranchs were quite large. A few gastropods were noted.

1,150 feet. — Color light brownish gray. Very slight trace of the quartz sand. The sample is a coarse calcareous gravel (comminuted rock) like the last. Foraminifera of several genera are numerous. Bits of madrepores are common. Some spines and plates of echini were observed. Lamellibranch remains very numerous. Gastropod shells not uncommon, and some genera noted not seen before. Ovules appear to be absent.

1,175 feet. — Color light brownish gray, like that of preceding. Very slight trace of the quartz sand. The sample consists largely of comminuted rock, but there are many rounded sand grains in it and a very few ovules; the latter were determined by their concentric structure. Foraminifera are numerous, but bits of coral (madrepores) are less abundant. A few spines and plates of echini were noted. Bryozoa numerous. Lamellibranchs are very abundant. Gastropods more common than usual.

1,200 feet. — Color light brownish gray. The limpid quartz sand is present as usual in very small amount. Sample seems to be a very finely comminuted rock, as it is made up for the most part of angular fragments. It is much finer grained than the last two, and there are fewer determinable fragments. No ovules. Foraminifera are common, and minute bits of coral (?) abound. Remains of echini are very scarce. Bryozoa rather common. Lamellibranch remains are very numerous, but there are very few gastropods.

1,225 feet. — Very light brownish gray. The quartz sand is present as a mere trace. The same is a very fine calcareous sand, most of the grains of which are rounded. No ovules. More than nine tenths passed through the sieve, and the rest is not very coarse. There are a few angular bits of limestone in the residue. Not much is determinable, but I noted a few foraminifera, many fragments of coral, some lamellibranchs, and a few gastropods (?).

1,250 feet. — Color very light brownish gray with many white particles. The amount of quartz sand is greater than it has been for 350 feet. The sample consists of a very fine grained calcareous sand, with comparatively few coarse particles in it, but in the latter are some angular bits of rock. Among the coarser particles are many foraminifera and bits of coral. Echini not noted. Bryozoa doubtfully recognized. Lamellibranchs, as well as gastropods, seem to be scarce. Some ovules and a few small bits of oölite were observed.

1,275 feet. — Color light brownish gray. Quartz sand present in small amount. The percentage of coarser material is greater than in the last two, and one can see in it bits of porous as well as compact limestone. Sample, aside from organic remains, consists largely of rounded grains. Ovules were observed, but they are very scarce (and may have come from 1,250 feet ?).

There are many foraminifera, and bits of coral are numerous. A few spines of echini were noted, and also a few bryozoa. Lamellibranchs are not numerous, and gastropods are very rare.

1,300 feet. — Color light brownish gray. Trace of quartz sand present. In the coarse portion of the sample there are many bits of porous rock, some of compact, and a few of oölitic. Much of the finer stuff is rounded. Some ovules. Foraminifera abound, and the curiously distorted *Orbitoides* have reappeared. Bits of coral are not uncommon, but there are very few remains of echini and bryozoa present. Lamellibranch remains are common, and gastropods are scarce. Noted some annelid (?) tubes. As usual, however, most of the material is unrecognizable.

1,325 feet. — Color light brownish gray. Almost no quartz sand, but an occasional particle may be noted in the fine stuff. Four fifths of the sample went through the No. 40 sieve. Originally a porous sand-rock? Ovules are rather numerous. Many foraminifera were noted, some of different genera than any heretofore observed. Bits of coral not uncommon. Echini seem to be absent. There are a few bryozoa. Lamellibranchs are common, but gastropods rare, as usual.

1,350 feet. — Color light brownish gray. Quartz sand very small in amount, but of same character as before. Comparatively little of the sample went through the sieve. The residue shows that the rock was very porous, and contained many rounded grains of sand and some ovules. The rock also contained some nodules of compact limestone. It appears to be different from the 1,325 foot sample. Determinable organic remains were not very abundant, but I noted foraminifera (*Orbitolites*, etc.), coral (?), two or three spines of echini, and a few bits of bryozoa. Gastropods (*Dentalium*, etc.) were scarce, and lamellibranchs not numerous.

1,375 feet. — Color light-brownish gray, with yellow cast. The quartz sand seems to be wanting. At least nine tenths of the sample went through the sieve as a rounded sand. In the residue are some bits of friable porous rock, and a few of compact stone, as if of nodules. Ovules (?) are present. Foraminifera are numerous, and some *Orbitoides* are large, one measuring 3.5 mm. across. *Textularia* appears. Several fragments of madrepores were noted. Spines of echini and the facetted bits are few in number, and so too are bryozoan, lamellibranch, and gastropod remains.

1,400 feet. — Very light brownish gray. Of quartz sand there is but a trace. The rock seems to have been a very porous limestone, and coarse, loosely compacted sand-rock containing nodules of solid limestone. Some ovules and a few bits of oölite were noted. Foraminifera are numerous, and some (*Orbitoides*) are as much as 4 mm. in diameter. The *Textularias* are common. Many bits of madrepore coral. A few spines and plates of echini. Bryozoa are very rare, and gastropods, and even lamellibranchs, are not common. The proportion of coarse material and determinable fragments is large.

1,425 feet. — Color very light yellowish brown. Quartz sand a mere trace, but the grains can be distinguished readily under the microscope, as is the case in all the samples where it is present at all. Originally was a loosely compacted fine-grained sand-rock with some solid limestone in it. Not much is recognizable. In the small determinable component were seen foraminifera (*Textularia*, *Orbitoides*, *Cristellaria*, *Orbitolites*, etc.), a few spines of echini, some remains of lamellibranchs (one is part of a comparatively large shell). It is doubtful whether any gastropods are present.

1,450 feet. — Color very light yellowish brown, with deep brown spots colored by limonite. The quartz sand is present as a mere trace. The rock seems to have been a very loosely compacted sand-rock, with a very few lumps and no solid limestone in it. The grains are rounded, and there are some ovules and bits of oölite in the material. Almost all the sample went through the sieve, and is too fine to be determinable. In the small residue were noted some foraminifera, an occasional bit of coral, and a few remains of lamellibranchs.

1,475 feet. — The color has changed decidedly to a pure light gray. A few angular particles of limpid quartz were noted. Scarcely one per cent failed to pass the sieve, and very little of this residue is determinable. As usual, most of the recognizable forms are foraminifera (sharply and obtusely pointed conical *Textularia*, *Cristellaria*, *Biloculina*, etc.). There are also bits of madrepore corals, millepores (?), branching bryozoans, and of lamellibranch shells and casts. The sample seems to be a very fine sand, without lumps or chips of solid rock.

1,500 feet. — Color light brownish gray. Quartz sand, — a mere trace. Sample is a very fine calcareous sand with a very few angular bits of rock in it. The sand consists of rounded and subangular particles. No ovules or oölite noted. Of the recognizable forms most were foraminifera, some of which were large (*Orbitoides*, *Textularia*, etc.). Some bits of coral and a very few spines of echini. Fragments of branching bryozoans were noted, and a few remains of lamellibranchs. Nothing could be determined even generically except the foraminifera.

1,525 feet. — Color light brownish gray, like the preceding. Quartz sand likewise a trace, — visible under the microscope and left as residue by HCl. Mostly a very fine sand, but in the coarser part are some relatively large pieces of a porous sand-rock, consisting of rounded grains with an occasional fossil. Organisms recognized: many foraminifera of several genera, the conical *Textularia* being the most common; a few bits of coral and branching bryozoans; lamellibranchs scarce and gastropods very scarce, but probably present.

1,550 feet. — Color light brownish gray. Quartz sand, — a mere trace, as usual. Appears to have been a porous limestone and sand-rock, none of which was solidly compacted. Foraminifera are very numerous, *Textularia* predominating. A few bits are doubtfully referred to madrepore coral. Remains of echini, branching bryozoa, lamellibranchs, and gastropods were noted, the last being very scarce.

1,575 feet. — Color light brownish gray, like the last. The angular limpid quartz sand is present as a mere trace. Seems to have been a moderately coarse sand-rock with much fine material in it, the grains are rounded, and there are some ovules present. A very few remains of echini, bryozoa, lamellibranchs and gastropods were observed, also *Textularia* in numbers, *Amphistegina*, etc., among foraminifera.

1,600 feet. — Color light brownish gray, with deep brown spots of limonite. Trace of quartz sand. A sand-rock containing lumps of compact limestone, as well as porous material not sand-rock. The determinable material was mostly foraminifera of several genera. There were also a few bits of madrepore corals, echinus spines, and branching bryozoa. Many remains of lamellibranchs and a few casts of gastropods. One piece of *Dentalium* was observed.

1,625 feet. — Color light brownish gray. The limpid quartz sand present as a slight trace. Again a rather loosely compacted coarse sand-rock with much very fine material in it. Contains some lumps of solid limestone and alse porous rock. Foraminifera very numerous and well preserved, the conical *Textularia* being especially abundant. Bits of coral, spines and plates of echini, and fragments of branching bryozoa are few. Pieces of lamellibranch shells are scarce, and casts of gastropods are very rare. Noted an occasional *Dentalium*.

1,650 feet. — Color light brownish gray. Trace of the quartz sand. The sample is very much like the last, with perhaps rather more chips of solid limestone in it. As usual foraminifera form a very considerable portion of the determinable remains. No bits of madrepore corals were noted. Spines and plates of echini are not scarce; some bryozoa are present; lamellibranch and gastropod remains are rare.

1,675 feet. — Color light brownish gray. Trace of the quartz sand. Sample appears very much like the last, but with fewer bits of solid and porous rock in it. It was mainly a sand-rock. Proportion of determinable remains smaller, perhaps, than in the last. Foraminifera of the usual genera abound; spines of echini are not rare; bryozoa, lamellibranchs, and gastropods occur very sparingly.

1,700 feet. — Color light brownish gray. Quartz sand rather more abundant than in the last three samples. The sample contains almost no angular fragments, and seems originally to have been a fine sand-rock. A few ovules? The proportion of determinable remains is very small. Foraminifera (*Textularia*, *Orbitolites*, etc.) are most numerous among them. Some spines of echini and bits of branching bryozoa were noted. Lamellibranch remains are unusually scarce and gastropods seem to be absent.

1,725 feet. — Color light brownish gray. A very small amount of the extremely fine quartz sand, in which is an occasional larger and more rounded grain. The rock seems to have been a moderately coarse sand-rock with much fine material in it, and the grains were rounded. A few ovules (?) were noted. Foraminifera of apparently the same genera as heretofore abound. Some fragments are doubtfully referred to coral. Spines of echini are comparatively numerous, and so too are branching bryozoa. Lamellibranchs are scarce and gastropods seem to be absent.

1,750 feet. — Color light brownish gray. Slight trace of quartz sand. This seems to be another rather coarse sand-rock with somewhat less fine material than the last, but containing also some solid and some porous limestone. A few ovules? Foraminifera abound, especially the textularias. A few fragments seem to be bits of madrepores. Spines (and plates) of echini are comparatively numerous. Some bryozoä are present, but lamellibranch remains are very scarce and gastropods seem to be absent.

1,775 feet. — Color light brownish gray. A very few particles of the angular quartz sand. Seems to have been a moderately coarse sand-rock like the preceding, but with very few bits of either solid or porous limestone. There seem to be a few ovules. Foraminifera of the several genera already noted are very abundant. Spines and plates of echini are comparatively numerous (perhaps some are from starfish). Some remains of lamellibranchs and a few minute gastropods were observed.

1,800 feet. — Color light brown with white particles. Trace of the quartz sand. The sample consists of a fine calcareous sand more than nine tenths of which passed through the No. 40 mesh sieve, and there are no very coarse particles in the residue, though there are a few small angular chips of solid limestone. Some ovules? Not much is determinable, but most of what is consists of foraminifera. Noted also a few spines of echini, some branching bryozoa, and a very few fragments of lamellibranchs. Gastropods seem to be absent.

1,825 feet. — Color light brownish gray with yellowish cast. Trace of the quartz sand. The sample is a fine calcareous sand, three fourths of which passed through the sieve. Some small angular bits of solid limestone appear in the coarser portion. Among the determinable forms foraminifera abound and the *Textularias* are the most numerous of these. *Orbitoides* also. There are also some spines of echini, a few bryozoa and lamellibranchs, and possibly a very few gastropods.

1,850 feet. — Color light brownish gray with yellowish cast, like the preceding. Quartz sand, a trace. The sample is a calcareous sand like the last, except that the proportion of coarser particles is rather greater. Organic contents like those of the last; mostly foraminifera of the usual genera with a few spines of sea-urchins, bryozoa, bits of lamellibranch shells and a very few gastropods. The *Textularias* predominate among the foraminifera. Among the coarser particles are some bits (or masses) of rather densely compacted sand-rock, and some angular bits of solid limestone.

1,875 feet. — Color light yellowish brown with many white particles. Trace of quartz sand. The sample is for the most part a very fine calcareous sand, nine tenths of which passed through the sieve. In the residue were some very angular bits of dense and porous rock and oölite. Loose ovules are not uncommon in the sand. Among the numerous foraminifera are some very large *Textularias*, *Orbitoides*, etc. A very few fragments look like madrepores. Spines and plates of echini are not rare. Bryozoa are scarce. There are a few remains of lamellibranchs and fewer of gastropods. One of the last is the internal cast of a purpuroid shell, possibly a *Pseudoliva*, about 3 mm. high. As usual, nearly all the sample consists of rounded, undeterminable grains.

1,900 feet. — Color light yellowish brown, with many white particles, like the preceding, but the amount of residue on sifting is even less than with that. A mere trace of the quartz sand is present. It is angular and limpid as usual. The sand may have been compacted to some extent, and there were some masses or layers of dense material in it, as is shown by some angular fragments. Some few ovules. Organic remains consist mostly of foraminifera. There are besides a very few bits of madrepores, some spines of echini, and a few bryozoa. Remains of lamellibranchs are few and of gastropods still fewer. Some rings look like parts of calcareous algæ, while others are portions of burrows and worm (?) tubes.

1,925 feet. — Color yellowish brown, white spots. Trace of the quartz sand, but it seems to be rather more than in the last. The sample is a very fine sand, very little (about 5% ?) failed to pass the sieve. Some ovules present, This sand also appears to have been compacted to some extent, or to have had compact lumps, and there are some angular fragments of dense limestone in the material. Determinable organic remains are few. There are mostly foraminifera of the usual genera. With these are some bits of madrepores (?), spines of echini, and bryozoa. Lamellibranch remains are rare, and those of gastropods were not observed. Some nullipores.

1,950 feet. — Color light yellowish brown. Quartz sand present in a very, very few particles of the finest grain (angular). Not more than two per cent of the sample failed to pass through the sieve. There were some lumps to indicate that the sand had been compacted to some extent. Some ovules. There were also a few angular bits of dense limestone containing organic remains. Very, very little of the sample is determinable. There are a few large foraminifera and some small ones. The large forms are *Textularia*. Some spines of echini were noted, and some pieces that were probably bryozoa. There were a very few remains of lamellibranchs, but none of gastropods were recognized.

1,975 feet. — Color light yellowish brown, with many white spots. Quartz sand, a mere trace. The sample is a very fine calcareous sand, like the last, with perhaps more compacted sand-rock in it. As before, there are a few angular bits or chips of dense limestone. In regard to organic remains it is like the last.

2,000 feet. — The color has changed to a light brownish gray. Quartz sand, a slight trace, an occasional particle of which is rounded and is too large to go through the sieve. Less than half the sample went through the sieve. The rock seems to have been a rather solid, very fossiliferous limestone. Foraminifera are very abundant, and of more than the usual genera, low conical and high conical *Textularias* predominating. Bits of madrepore corals present in small numbers. Spines, plates, and larger fragments of sea-urchin tests are not uncommon. Several fragments of branching bryozoa were observed, and a few pieces of lamellibranch shells and casts, as well as a very few casts of minute gastropods.

Analyses of Artesian Well Borings, Key West, Florida.[1]

	25 ft.	100 ft.	150 ft.	350 ft.	600 ft.	775 ft.	1,125 ft.
SiO_2	.17	.25	.12	3.52	5.10	.13	.05
Al_2O_3	.20	.17	.08	.40	.35	.14	.21
Fe_2O_3	.07	.07					
CaO	54.03	54.01	54.38	51.46	48 87	46.53	53.84
MgO	.29	.77	.86	1.67	2.50	6.70	.86
CO_2	42.52	42.84	43.36	41.77	40.72	43.60	42.87
	97.28	98.11	98.80	98.82	97.54	97.10	97.83

	1,325 ft.	1,400 ft.	1,475 ft.	1,625 ft.	1,850 ft.	2,000 ft.
SiO_2	.07	.19	.06	.05	.03	.07
Al_2O_3 Fe_2O_3	.11	.16	.14	.17	.17	.16
CaO	54.49	55.12	54.48	53.90	54.28	54.02
MgO	.62	.80	.78	1.14	1.12	1.06
CO_2	43.29	43.28	43.33	43.37	43.18	43.20
	98.58	99.05	98.79	98.63	98.78	98.51

All the above samples contain more or less P_2O_5. This, together with any TiO_2 that may be present, shows as Al_2O_3 above.

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[1] By George Steiger. F. W. Clarke, Chief Chemist.

Record of the Artesian Well at Key West, Florida.

Depth.	Color.	Texture.	Quartz Sand.	Foram.	Corals.	Echin.
Surface.	Yel. wh.	Oölite.	Merest trace.	. . . .	. . . .	. . .
25	Yel. wh.	Oölite.	None.	. . . .	. . . .	. . .
50	White.	Compact, with some oölite.	None.	*	+	+
75	Lt. gray.	Partly compact and partly porous.	A small amt.	+	+	. . .
100	White.	Compact, with some oölite.	Trace.	. . . .	+	. . .
125	White.	Porous, with compact portions.	A small amt.	. . . .	+	. . .
150	Yel. wh.	Compact and hard.	Trace.	. . . .	+	+
175	White.	Compact, w. porous portions.	A small amt.	. . . .	+	+
200	White.	Fine sand rock, partly compact. Slightly yellowish tinge.	Ditto.	. . . .	+	+
225	White.	Rather porous, partly oölitic.	Ditto.	. . . .	Very few.	+
250	White.	Soft, porous, granular, somewhat oölitic.	Relatively large amount.	. . . .	. . . .	. . .
275	White.	Rather solid sand-rock, with some amorphous limestone.	Ditto.	. . . .	Very few.	. . .
300	White.	Sand-rock, with some dense limestone and a little oölite.	Ditto.	. . . .	?	. . .
325	Yel. wh.	Sand-rock, containing a few ovules.	Ditto.	+	. . . .	*
350	Yel. wh.	Rather coarse sand-rock.	Small amount.	. . . .	+	+
375	Yel. wh.	Rather coarse sand-rock, containing a few ovules and some dense limestone.	Ditto.	. . . .	+	+
400	Gray.	Loosely compacted sand-rock, containing porous hard white portions. Partly oölitic.	Present in notable amount.	Very few.	+	. . .
425	Gray.	Sand-rock, like the last above.	Relatively large amount.	. . . .	Few.	Few.
450	Gray.	Ditto.	Very small amt.	. . . .	. . . .	. . .
475	Gray.	Ditto.	Small amount.	. . . .	. . . .	+
500	Gray.	Ditto, with the addition of gray dense limestone.	Ditto.	. . . .	+	*
525	Gray.	A friable sand-rock, with lumps of hard, white, porous limestone.	Ditto.	. . . .	?	+
550	Dk. gr.	Very friable sand-rock, with almost no bits of the white.	Ditto.	. . . .	. . . .	. . .
575	Dk. gr.	Ditto; with oölite present.	Ditto.	+	Rare.	. . .
600	Lt. gr.	Friable sand-rock, with many bits of white.	Sm. amt, very fine grained.	. . . .	. . . .	?
625	Gray.	Like the above, but w. fewer white bits. Some ovules.	Ditto.	+	. . . .	?
650	Gray.	Ditto; with pieces of oölite.	Very sm. amt., and very fine grained.	. . . .	. . . .	+
675	Gray.	Ditto; with pieces of oölite.	Ditto; but with more of the larger rounded grains.	+	. . . .	+

Record of the Artesian Well at Key West, Florida.

Bryozoa.	Lamel.	Gastr.	Remarks.
....	....	....	This is a somewhat friable oölite. The quartz sand is very fine, limpid, angular.
....	....	....	Very friable oölite.
....	*	Few.	Mainly a shell limestone with much foraminiferal rock and oölite.
....	+	....	Almost white in color.
....	*	...	Pectinoids were noted among the lamellibranchs.
....	*	....	Partly an oölite, some of which is firm and some friable. There are many isolated ovules. Mostly a very porous rock.
....	*	....	Many rounded grains in the rock, but very little true oölite. Many angular bits of dense crystalline limestone.
....	*	....	Like the preceding in the main.
+	+	+	Sample is a fine sand containing very few determinable organic remains.
+	*	Very few.	Relatively coarse *rounded* grains of quartz are present. Very few determinable organic remains.
....	Very few.	....	Some of the rounded grains of quartz are 1 mm. in diameter.
+	*	....	Determinable remains very scarce.
+	+	Very few.	Noted some nullipores? Structure in thin section resembling the Palæozoic *Stromatopora*. [Can this be a nullipore?]
+	+	Very few.	Noted some nullipores? and some annelid tubes singly (*Spirorbis?*) and in groups.
....	+	....	A few relatively large fragments of coral are in the sample, and some annelid tubes.
....	*	....	Remains of some annelid tubes are present. Very, very little of the sample is determinable.
+	*	Very few.	Nullipores? and annelid tubes are present.
Very few.	*	....	The quartz sand contains relatively large, rounded grains. A single minute brachiopod (*Cistella?*) was noted.
....	Scarce.	....	Fewer of angular fragments of solid limestone than in 425. Almost no determinable remains.
Very few.	+	....	Still less solid limestone. Next to nothing determinable.
+	*	Very rare.	Thin section shows an organism made up of branching, anchylosed tubes similar to that in 300.
....	*	....	A fragment shows the network of tubes like that at 500 and 300 feet. Some lumps of oölite.
....	....	....	The quartz sand is relatively coarse and rounded. Recognized no determinable fragments of organisms.
+	+	Rare.	Foraminifera are *Amphistegina?* and *Cristellaria?*
....	+	....	A few ovules. Almost nothing determinable. Considerable granular calcite.
....	+	....	Some ovules. Almost nothing determinable. Branch of a calcareous alga?
....	+	....	Piece of an alga? Almost nothing determinable.
....	+	....	Great dearth of referable organic remains.

Record of the Artesian Well at Key West, Florida.

Depth.	Color.	Texture.	Quartz Sand.	Foram.	Corals.	Echin.
700	Yel. wh.	Uncompacted? sand with ovules and sm. bits of oölite.	Very, very sm. amount.	. . . .	. . . .	+
725	Yel. wh.	Mostly a "shell rock," with some oölite.	Trace.	*	. . . .	+
750	Yel. wh.	Porous rock, with ovules.	Very sm. amt.	+	. . . .	+
775	Very light yel. brn.	A hard porous rock with a few ovules.	Trace.	?	. . . .	+
800	Ditto.	Ditto.	More than the last 4 above.	*	. . . .	+
825	Ditto.	Ditto? More oölitic.	Small amount.	+	. . . .	+
850	Ditto.	Fine, uncompacted? sand, with many ovules.	Trace.	*	. . . .	. . .
875	Ditto.	Ditto, with few ovules.	Trace.	. . . .	. . . .	+
900	Ditto.	Loosely compacted sand-rock, with few ovules.	Trace.	*	+	. . .
925	Ditto.	Looks like a rather coarse beach sand.	Trace.	*	+	+
950	Ditto.	Ditto, with many ovules. Color a shade darker.	Trace.	*	+	?
975	Ditto.	Ditto, but contains angular fragments of rock.	Scarcely perceptible.	*	+	+
1000	Ditto.	Rather coarse sand-rock with rounded grains. Color a shade darker.	Ditto.	*	*	+
1025	Ditto.	A fine sand-rock with rounded grains.	Trace.	*	+	. . .
1050	Ditto.	Ditto.	Trace.	*	+	. . .
1075	Ditto.	Very fine sand-rock, with few ovules.	Trace, slight.	+	+	Scarce.
1100	Lt. brn. gr.	Partly porous and partly dense limestone.	Trace, slight.	*	*	+
1125	Lt. brn. gr.	Ditto.	Trace, slight.	*	*	Scarce.
1150	Lt. brn. gr.	Ditto.	Trace, slight.	*	+	+
1175	Lt. brn. gr.	Ditto, partly oölitic.	Trace, slight.	*	+	+
1200	Lt. brn. gr.	More of a sand-rock than the four above, but much of it dense.	Very sm. amt.	*	*	Scarce.
1225	Very light brn. gr.	Very fine sand-rock, with many grains rounded.	Trace.	+	*	. . .
1250	Ditto.	Fine sand-rock, with some dense portions.	More than for 350 ft. above.	*	*	. . .
1275	Lt. brn. gr.	Sand-rock, with partly porous and partly dense portions.	Small amount.	*	*	+
1300	Lt. brn. gr.	Ditto.	Trace.	*	+	Scarce.
1325	Lt. brn. gr.	Fine sand-rock with ovules.	Trace.	*	+	. . .
1350	Lt. brn. gr.	A porous sand-rock, w. some dense portions and ovules.	Very sm. amt.	+	?	+
1375	Lt. yel. brn.	A fine sand-rock, with porous and dense portions and some ovules.	Wanting?	*	+	+
1400	Very light brn. gr.	Ditto.	Trace.	*	*	+

Record of the Artesian Well at Key West, Florida.

Bryozoa.	Lamel.	Gastr.	Remarks.
....	+	....	Looks like a loose beach sand, with almost no referable organic remains. Quartz grains various in size.
+	*	+	A globular foraminifer is rather abundant. The lamellibranchs are larger than usual.
+	*	+	More gastropods than usual. Some corallines?
....	*	+	Highly fossiliferous. Shells and casts of pectinoid and other lamellibranchs most abundant.
+	*	+	Some shell fragments show the effects of boring organisms.
+	*	+	Annelid? tubes and spicules of *Gorgonia*. More secondary calcite than usual.
....	*	+	Spicules of *Gorgonia* rather numerous.
....	+	....	Spicules of *Gorgonia* present. Sample is meagre in determinable fragments.
....	*	....	Nullipores? and spicules of *Gorgonia* present. *Orbitoides* appear in numbers.
+	*	Rare.	*Orbitoides* abounds. Spicules of *Gorgonia* not rare. Many white particles are in the sample.
Rare.	+	Rare.	Spicules of *Gorgonia* noted. Small proportion of referable organic remains.
....	*	Rare.	Seems to have been a loosely compacted rather coarse sandrock.
+	*	+	Annelid tubes and *Vermetus?* *Cæcum* and *Dentalium*. Spicules of *Gorgonia*. Gastropods more numerous than usual.
+	*	+	Foraminifera very abundant. Gastropods comparatively so. *Cæcum* and *Dentalium* present.
+	+	Scarce.	Largely composed of tests of foraminifera.
+	+	....	Very little is determinable.
+	*	+	Much more coarse material than in last above.
+	*	+	Fewer foraminifers than in preceding. The remains indicate comparatively large lamellibranchs.
....	*	+	Gastropods relatively common.
+	*	+	Gastropods more common than usual. Bits of coral less abundant than in the last above. Nullipores present.
+	*	Very few.	Few determinable fragments.
....	+	Very few.	Very, very little is determinable. There are a few angular bits of limestone present.
?	Scarce.	Very few.	Somewhat oölitic.
+	+	Very few.	Ovules are present, but scarce.
Scarce.	+	Very few.	Somewhat oölitic. As usual, most of the material is undeterminable.
+	*	Very few.	Very, very little is determinable.
+	+	+	Sample contains many angular fragments, but they contain very few determinable organic remains. Many rounded grains.
Few.	Few.	Few.	Some *Orbitoides* are very large, one 3.5 mm. across. *Textularias* appear. Very little coarse material, however.
Very few.	Few.	Few.	Foraminifers numerous and large, 4 mm.; many *Textularias*. The proportion of determinable fragments is large.

Record of the Artesian Well at Key West, Florida.

Depth.	Color.	Texture.	Quartz Sand.	Foram.	Corals.	Echin.
1425	Lt. yel. brn.	Fine loose sand-rock, with a very little solid limestone.	Trace.	*	. . . .	+
1450	Lt. yel. brn.	A very fine loose sand-rock.	Trace.	+	Rare.	. . .
1475	Lt. gray.	Ditto.	Trace.	+	+	. . .
1500	Lt. brn. gr.	Ditto, with a very little solid limestone in it.	Trace.	*	+	Scarce.
1525	Lt. brn. gr.	A fine, loosely compacted sand-rock.	Trace.	*	+	. . .
1550	Lt. brn. gr.	A porous limestone and sand-rock.	Trace.	*	?	+
1575	Lt. brn. gr.	A moderately coarse sand-rock, with some ovules.	Trace.	*	. . . .	+
1600	Lt. brn. gr.	A sand-rock containing porous and dense limestone.	Trace.	*	+	+
1625	Lt. brn. gr.	Ditto.	Trace.	*	+	+
1650	Lt. brn. gr.	Ditto, with more dense limestone.	Trace.	*	. . . .	+
1675	Lt. brn. gr.	Ditto; with less dense and porous limestone.	Trace.	*	. . . .	+
1700	Lt. brn. gr.	A fine sand-rock.	Very sm. amt.	*	. . . .	+
1725	Lt. brn. gr.	A moderately coarse sand-rock; rounded grains.	Very sm. amt.	*	?	+
1750	Lt. brn. gr.	Ditto, with some solid and some porous limestone.	Trace.	*	?	+
1775	Lt. brn. gr.	Ditto, with very little limestone.	Very little.	*	. . . .	+
1800	Lt. brn.	A very fine sand-rock, with very little solid limestone.	Trace.	*	. . . .	+
1825	Lt. yel. brn.	Ditto.	Trace.	*	. . . .	+
1850	Lt. yel. brn.	Ditto; but more solid rock.	Trace.	*	. . . .	+
1875	Lt. yel. brn.	Ditto, with some dense and some porous rock and oölite.	Trace.	*	?	+
1900	Lt. yel. brn.	A very fine sand-rock, with a little limestone and some ovules.	Trace.	*	+	+
1925	Lt. yel. brn.	Ditto.	Very little.	*	?	+
1950	Lt. yel. brn.	A very, very fine sand-rock with some ovules and a very little limestone.	Trace.	+	. . . .	+
1975	Lt. yel. brn.	Ditto.	Trace.	+	. . . .	+
2000	Lt. brn. gr.	Seems to have been a rather solid, very fossiliferous limestone.	Trace.	*	+	+

N. B. — In the foregoing table the sign + is used to indicate the presence of the organism in question in fair numbers for the sample concerned; and the asterisk is used to indicate a still larger number, comparatively. Such comparison is intended to be made only along the horizontal lines.

Record of the Artesian Well at Key West, Florida.

Bryozoa.	Lamel.	Gastr.	Remarks.
. . . .	+	. . . .	Not much is determinable, but what there is is mostly foraminiferal.
. . . .	+	. . . .	Almost all the sample went through the sieve, and is not determinable.
+	+	. . . .	Scarcely one per cent failed to pass the sieve.
+	+	. . . .	Very little is determinable.
+	Few.	?	The *Textularias* are the most common fossil.
+	+	Very few.	*Textularias* predominate among the foraminifera.
+	+	+	Much very fine sand in the sample. *Textularias* predominate, as above.
+	*	+	One piece of *Dentalium* observed.
+	Scarce.	Very few.	Highly foraminiferal, especially with *Textularia*. A few pieces of *Dentalium* were noted.
+	Scarce.	Very few.	Highly foraminiferal.
Few.	Few.	Few.	Proportion of determinable fragments rather small.
+	Very few.	. . . .	Very little is determinable. Ovules present?
+	Very few.	. . . .	The quartz sand contains relatively large, rounded grains. Some granules are doubtfully referred to ovules.
+	Very few.	. . . .	The *Textularias* are abundant. Ovules?
. . . .	+	Very few.	Highly foraminiferal, with same genera. Ovules?
+	+	. . . .	Foraminifera constitute the major part of what little is determinable. Ovules present?
+	+	?	Small proportion determinable; mostly foraminifera; particularly *Textularias* and *Orbitoides*.
+	+	+	Ditto.
Scarce.	+	Very few.	Contains internal cast of a *Pseudoliva*? 3 mm. high.
+	Few.	Very few.	Some fragments resemble calcareous algæ, while others are portions of burrows and worm tubes.
+	Few.	. . . .	Some fragments doubtfully referred to nullipores.
+	Few.	. . . .	Almost nothing determinable.
+	Few.	. . . .	Almost nothing determinable.
+	+	Very few.	An occasional rounded particle is too large for the sieve No. 40. *Textularias* predominate among the abundant foraminifera.

The following Publications of the Museum of Comparative Zoölogy are in preparation: —

Reports on the Results of Dredging Operations in 1877, 1878, 1879, and 1880, in charge of ALEXANDER AGASSIZ, by the U. S. Coast Survey Steamer "Blake," as follows: —

A. MILNE-EDWARDS. Crustacea of the "Blake."
E. EHLERS. The Annelids of the "Blake."
C. HARTLAUB. The Comatulæ of the "Blake," with 15 Plates.
H. LUDWIG The Genus Pentacrinus.
A. E. VERRILL. The Alcyonaria of the "Blake."

Illustrations of North American MARINE INVERTEBRATES, from Drawings by BURKHARDT, SONREL, and A. AGASSIZ, prepared under the Direction of L. AGASSIZ.

A. AGASSIZ and A. G. MAYER. The Acalephs of the East Coast of the United States.
" " " On Dactylometra quinquecirra Agass.
AGASSIZ and WHITMAN. Pelagic Fishes Part II., with 14 Plates.
LOUIS CABOT. Immature State of the Odonata, Part IV.
E. L. MARK. Studies on Lepidosteus, continued.
" On Arachnactis.
R. T. HILL. On the Geology of the Isthmus of Panama.
" On the Geology of Jamaica.
CHARLES WACHSMUTH and FRANK SPRINGER. The North American Fossil Crinoidea Camerata. With an Atlas of 83 Plates. Will be issued as Vols. XX. and XXI. of the Memoirs.

Contributions from the ZOÖLOGICAL LABORATORY, in charge of Professor E. L. MARK, as follows: —

W. WHITNEY. The Histology of Thyone.
T. G. LEE. The Suprarenals in Amphibia.

Contributions from the GEOLOGICAL LABORATORY, in charge of Professor N. S. SHALER.

Studies from the NEWPORT MARINE LABORATORY, communicated by ALEXANDER AGASSIZ.

Reports on the Results of the Expedition of 1891 of the U. S. Fish Commission Steamer "Albatross," Lieutenant Commander Z. L. TANNER, U. S. N., Commanding, in charge of ALEXANDER AGASSIZ, as follows: —

A. AGASSIZ. The Pelagic Fauna.
" The Echini.
" The Panamic Deep-Sea Fauna.
J. E. BENEDICT. The Annelids
K. BRANDT. The Sagittæ.
" The Thalassicolæ.
C. CHUN. The Siphonophores.
" The Eyes of Deep-Sea Crustacea.
W. H. DALL. The Mollusks.
S. GARMAN. The Fishes.
H. J. HANSEN. The Cirripeds and Isopods.
W. A. HERDMAN. The Ascidians.
S. J. HICKSON. The Antipathids.
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G. VON KOCH. The Deep-Sea Corals.
C. A. KOFOID. Solenogaster.
R. VON LENDENFELD. The Phosphorescent Organs of Fishes.
C. F. LÜTKEN and TH. MORTENSEN. The Ophiuridæ.
O. MAAS. The Acalephs.
E. L. MARK. The Actinarians.
JOHN MURRAY. The Bottom Specimens.
ROBERT RIDGWAY The Alcoholic Birds.
P. SCHIEMENZ. The Pteropods and Heteropods
W. PERCY SLADEN. The Starfishes.
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THEO. STUDER. The Alcyonarians.
M. P. A. TRAÜTSTEDT. The Salpidæ and Doliolidæ.
E. P. VAN DUZEE. The Halobatidæ.
H. B. WARD. The Sipunculids.
H. V. WILSON. The Sponges.
W. McM. WOODWORTH. The Planarians.

PUBLICATIONS

OF THE

MUSEUM OF COMPARATIVE ZOÖLOGY

AT HARVARD COLLEGE.

There have been published of the BULLETINS Vols. I. to XXIX.; of the Memoirs, Vols. I. to XVIII.

Vols. XXVIII. and XXX. of the BULLETIN, and Vol. XIX. of the MEMOIRS, are now in course of publication.

The BULLETIN and MEMOIRS are devoted to the publication of original work by the Professors and Assistants of the Museum, of investigations carried on by students and others in the different Laboratories of Natural History, and of work by specialists based upon the Museum Collections.

The following publications are in preparation: —

Reports on the Results of Dredging Operations from 1877 to 1880, in charge of Alexander Agassiz, by the U. S. Coast Survey Steamer "Blake," Lieut. Commander C. D. Sigsbee, U. S. N., and Commander J. R. Bartlett, U. S. N., Commanding.

Reports on the Results of the Expedition of 1891 of the U. S. Fish Commission Steamer "Albatross," Lieut. Commander Z. L. Tanner, U. S. N., Commanding, in charge of Alexander Agassiz.

Contributions from the Zoölogical Laboratory, in charge of Professor E. L. Mark.

Contributions from the Geological Laboratory, in charge of Professor N. S. Shaler.

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ALEXANDER AGASSIZ, *Director.*

1905

THE WESTERN SIERRA MADRE
OF THE
STATE OF CHIHUAHUA, MEXICO.

BY

EDMUND OTIS HOVEY.

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THE WESTERN SIERRA MADRE OF THE STATE OF CHIHUAHUA, MEXICO.

BY

EDMUND OTIS HOVEY.

The region comprised in Western Chihuahua, eastern Sonora, and southward in Mexico along the zone of mountains known as the Western Sierra Madre is practically a terra incognita to geologists and geographers. It includes the region left uncoloured on Costillo's geological map of Mexico as being unknown. Here and there mining engineers have examined bits of property for individual or corporate mine owners; but their reports rarely contain any structural data, and are seldom published in journals. The archæologist has penetrated into some of the mountain fastnesses, but he has given us scarcely a glimpse of the physiographic wonders of the region. No correct map of the mountains and rivers is in existence; but the railroad surveys now under way, in the effort to connect the high plateau with the Pacific coast region, should ere long furnish us with valuable data for one.

With the prospect, therefore, of traversing virgin territory, Professor Robert T. Hill and the writer* turned their faces toward the Southwest last winter, and spent several weeks in a remarkable series of cañons and mesas which will be described in a summary manner in the present communication, which gives some of the results of our joint observations. Our route led us southwestward across the Chihuahua desert province over the new Rio Grande, Sierra Madre and Pacific Railway to its present terminus at Nuevas Casas Grandes, Chihuahua, about 150 miles from El Paso, Texas, and from the very beginning the journey was suggestive.

The stratified beds of the arid and semi-arid regions of western America have given rise to much discussion as to their origin. Great lakes have been assumed to account for the extensive terraces, but it is difficult to conceive of the permanent or even protracted existence of large bodies of water under the conditions obtaining in the region. The cycle of the "mesa," or desert, formations was made clear by this little railroad journey across the arid bolsons to Lake Guzman and thence up the Casas Grandes, or

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* The latter as the representative of the American Museum of Natural History.

San Miguel River. Under the influence of the great diurnal changes of temperature of the elevated plateau, and consequent expansion and contraction, the volcanic materials making up the mountains crack and disintegrate. The fragments as they descend the slopes become smaller, and soon come within the transporting power of the heavy winds which often prevail upon the plateaux.

The broken-down material is rapidly carried into the basins which lie between the numerous old centres of eruption and gradually fills them. From time to time the water collects in these depressions, and more or less temporary ponds are formed, which act like settling tanks—a term suggested by Professor Hill. Well-stratified beds thus originate within the wind-drifted areas and between beds showing little or no stratification. This explains the occurrence of some of the lenticular deposits of adobe clay in the strata composing the mesas. Robert T. Hill and others have written much upon the geology of desert and arid regions, but this explanation of the origin of some of the adobe clay deposits seems to have been overlooked.

The particular feature of the copious drainage of the high plateaux of the Western Sierra Madre is that most of the streams either dry up in the desert or flow into lakes which have no outlet. The Conchos, however (a tributary of the Rio Grande), is slowly working its way back toward the high plateau from the east; while the Yaqui and its branches, the Mayo and other Pacific rivers, are cutting into the plateau from the west with greater rapidity.

Lake Guzman, eighty miles from El Paso, is one of the largest of the desert lakes. It is 25 miles long and from 10 to 15 miles wide, and the evaporation from its surface is said to amount to seven feet per annum. The lake is reported to have been entirely dried up in August, 1904. The principal stream flowing into Lake Guzman is the Corralitos, or Casas Grandes River, and we followed this nearly to its source. Like other streams flowing into deserts, the maximum volume of this river is not near its mouth, but is near its entrance into the region where evaporation equals or exceeds precipitation.

The river which is known as the Corralitos for part of its course and the Casas Grandes for the rest is formed by the union of the San Miguel and Piedras-Verdes Rivers about ten miles south of the town of Casas Grandes, which received its name from neighbouring extensive prehistoric ruins. The San Miguel is the principal of these tributaries, and should give its name to the whole river, or else the name Corralitos should be applied to the whole, the name Casas Grandes not being sufficiently distinctive on account of other regions of extensive ruins in Mexico. Many rivers in Mexico are known by different names in different parts of their courses—a practice which leads to much unnecessary confusion in geographic nomenclature.

Most of the mountains in sight from the railroad are volcanic in origin, but the Sabinal Mountains, about 100 miles from El Paso, are granitic in character, overlain by "porphyry" and by limestone of Cretaceous age. This is the location of the San Pedro group of silver and lead mines. Advancing southward from the end of the railroad as far as the Aros (Yaqui) River, 80 miles in an air-line, the rocks are almost exclusively volcanic, mostly rhyolite and andesite and their accompanying tuffs and dikes, together with comparatively local sandstones and conglomerates which have been derived directly from the volcanic materials and which represent ancient mesa and fresh-water basin formations. East of Hacienda San Diego blue limestone, probably of Cretaceous age, occurs in the foothills, and is quarried on a small scale for burning into lime.

About fourteen miles south of San Diego we began our ascent from the Chihuahua desert to the high plateau by way of the San Miguel cañon, and followed up its winding course for ten or twelve miles. The river is in a period of rejuvenation, and cuts a narrow, deep gorge 300 to 500 feet deep in a well-dissected plain which rises gradually to the cliffs forming the walls of the outer or upper cañon. The whole cañon is six or seven miles wide and about 1,800 feet deep. The principal rocks exposed are rhyolite flows and tuffs, but basalt occurs at the northern end of the cañon, and rounded andesite hills are under the rhyolite cap toward the south. The scenery is varied and beautiful.

Following the Arroyo Metate and another great ravine without a name, we climbed out of San Miguel cañon, and came upon the great plateau at 6,500 feet,* after passing over the outer rim of the cañon at 7,200 feet above the sea. The plateau is divided up into great haciendas or cattle-raising estates, the most valuable portions of which are immense nearly level plains or basins, most of which have no drainage outlet. The extensive plain, or prairie, known as the Llano Cristo forms a portion of the San Miguel hacienda, one of many belonging to General Luis Tarrazas, Governor of the

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* All the elevations given in this article were determined by means of an aneroid barometer.

State of Chihuahua. The plateau is a constructional plain formed by the upper surface of rhyolite flows, with its hollows partly filled by the wash from the higher portions.

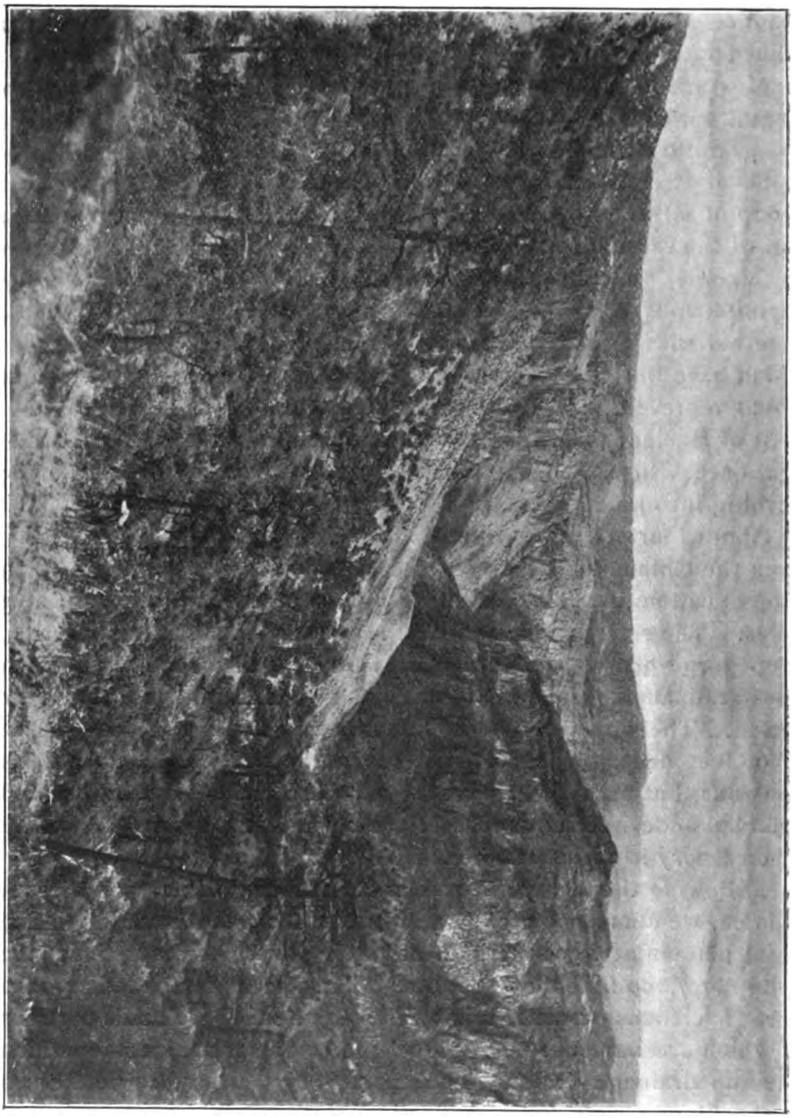

FIG. 1—VAQUI (AROS) CAÑON, NEAR GUAYNOPITA RIVER, IS 5,200 FEET LOWER THAN DISTANT RIM. INNER GORGE ABOUT 2,000 FEET DEEP.

The surface features of these plains would form an interesting topic for geographic study. Part of the Llano Cristo has been captured by the San Miguel (Casas Grandes) drainage; but much of it is still independent, and none of the water falling upon this portion of the high plateau of Mexico reaches either ocean. The Llano Cristo contains some of the sources of the San Miguel River, and is about 2,500 feet above the arid waste in which that stream loses itself.

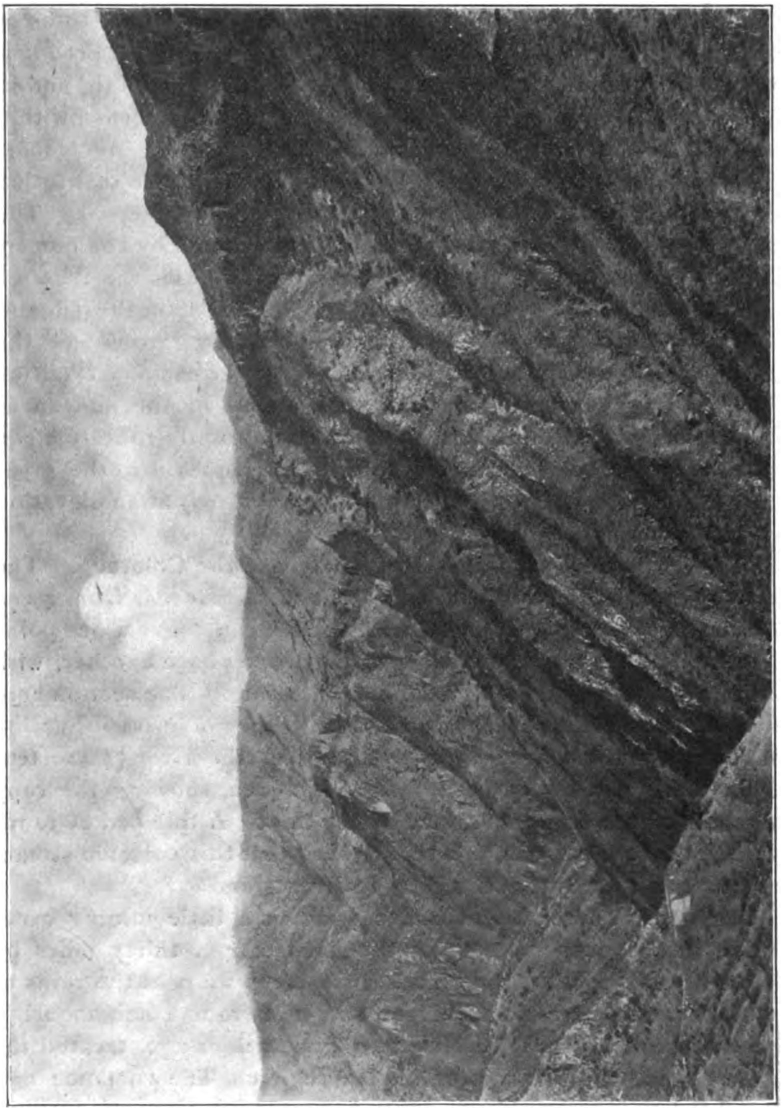

FIG. 2.—YAQUI (AROS) CAÑON AT GUAYNOPITA, 5,200 FEET DEEP. LOWER GORGE 1,800 FEET DEEP.

Southward from Hacienda San Miguel our route lay along the extensive prairies of the high mesa and across the spurs sent down from the mountain ranges, which traverse the plateau in a general north-south course. The mountains rise only from 1,500 to 2,500 feet above the mesa, and rarely is there a peak the altitude of which is more than 9,000 feet above the sea. All appear to be of volcanic origin, rhyolite and andesite lavas and tuffs predominating. The mesa itself gradually rises toward the south, and in the Llano Bavicora, a beautiful prairie 20 or 30 miles across, within the Hearst estate, is 7,000 to 7,100 feet in elevation. Moctezuma Pass (7,282 feet) is gained and crossed with scarcely a realization that the so-called "continental divide" has been traversed. The site of a large prehistoric village or city is indicated by the numerous mounds of the gently-rounding plain which forms the "Pass."

The inland drainage ceases here, and we are upon the edge of the Pacific drainage system, which is gradually "robbing" the plateau drainage. The newly-established lumber camp of Diedrick is in the mountains, just west of the summit of the plateau at Moctezuma Pass. Here the mountains rise abruptly to fully 9,000 feet above tide, and the trail to Guaynopita passes into the great cañon of the Yaqui River (here known as the Aros) at an elevation of 8,330 feet.

The view rivals that of the Grand Cañon of the Colorado. The Aros cañon is from 8 to 10 miles wide, and the river is from 4,500 to 5,000 feet below the highest points of the rim. From one point there may be seen nineteen flows of lava, one above another, with intervening beds of tuff and local conglomerate. The section here exposed gives additional support to the theory of mesa formation above expounded. Where the trail crosses the river (4,400 feet A. T.) there is a heavy bed of andesitic lava, showing the ropy character of the original surface of the flow. A thin bed of sandstone lies directly upon the lava, showing that this volcanic stream was covered with water soon after its extrusion.

Guaynopita, our next objective point, is a little mining camp hidden in the deep recesses of the Aros cañon, thirty miles by trail west of Diedrick. In reaching the camp we pass the ruins of an old arrastra, or mill, and the slag-pile from a neighbouring ancient furnace, where the Mexicans, generations ago, treated the copper, gold, and silver ores of the region. The romance and tragedy of mining have been carried through all these marvellous ravines, gorges, and cañons. At Guaynopita itself there is a splendid example of intrusive granite, associated with limestone. The limestone appears to be of late Cretaceous age; hence, the granite is post-Cretaceous. Beautiful over-thrust faults are shown in the limestone, and in places metamorphism of the rock has gone so far as to produce schist. The ores (mostly chalcopyrite, cuprite, and tetrahedite) occur disseminated through the granite and concentrated in quartz veins which traverse granite and limestone alike. The little district of Guaynopita is one of the most inter-

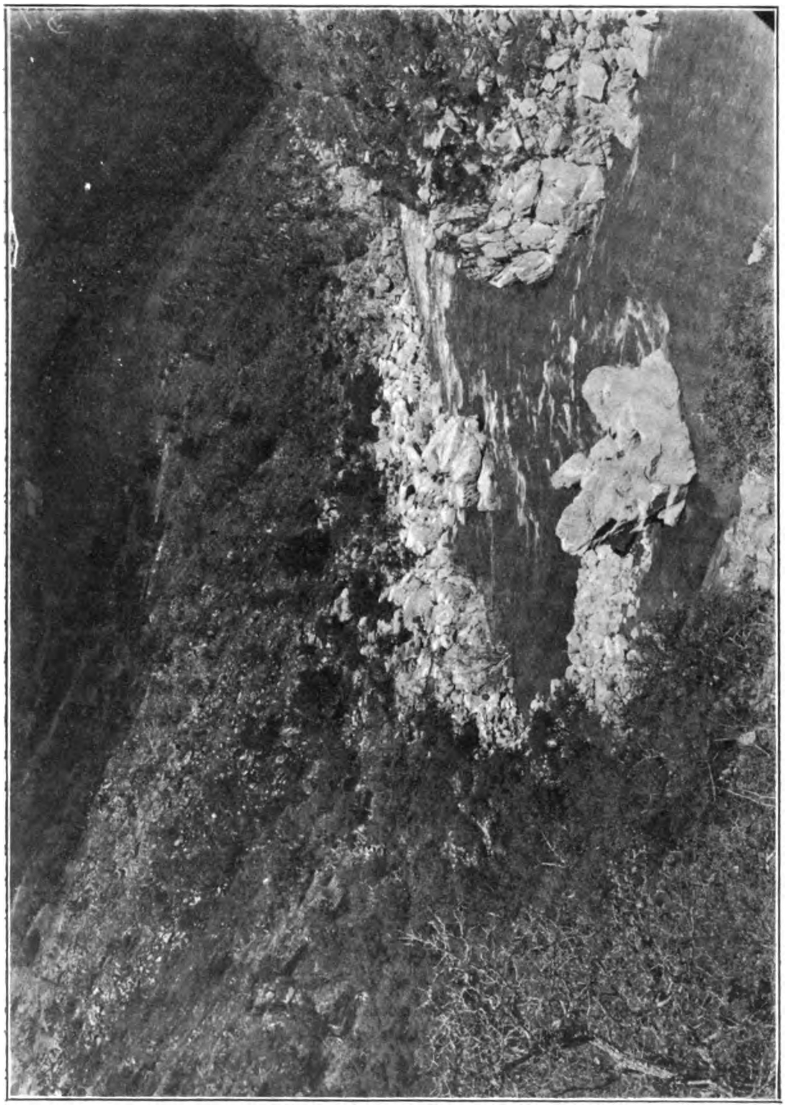

FIG. 3.—YAQUI (AROS) RIVER AT GUAYNOPITA. SHOWS ABANDONED CHANNEL AT LEFT OF PRESENT COURSE.

esting geological regions in existence, and several forms of ore deposits occur therein.

Leaving Guaynopita, our course lay somewhat east of south for four days along the high mesa, between the Aros River on the east and an important tributary, the Tutuaca, on the west. The mesa, or series of mesas, extending southward between these two rivers has a gentle dip toward the east and south; hence, the natural course of the streams of this region at first was toward the southeast, and the smaller streams still preserve this consequent course; but the master river, the Yaqui (Aros), and the Verde, the Tutuaca, and the Mulatos pursue an inverted course. The Chico alone of the great tributaries of the Yaqui (Aros) preserves its consequent course along the eastern slopes of the Candelaria Mountains. In several places the table-land is reduced to a narrow divide between the eastward and westward flowing drainage; but everywhere the western slopes are the steeper—the heads of the streams are being constantly pushed toward the east.

Twenty-five miles southeast of Guaynopita we encountered the old Temosachic-Dolores trail, and its well-worn mule-tracks looked like a highway across the Mesa Venado. For generations this was the route traversed by the hundreds of pack-trains needed for carrying supplies from Chihuahua to the mines of the Sierra Madre and for bringing back ore and bullion. Very recently a new route leading to the railway at Miñaca, with gentler grades, has been established farther south by American enterprise. Mesa Venado is several miles long and more than a mile wide; and lying as it does 7,400 feet above the sea, it supports a magnificent forest of the long-leafed sugar-pine. The timber of the high mesa is the real incentive for pushing forward the railroads, which are to make their way from the central plateau down to the Pacific Ocean.

Turning abruptly westward, we plunged from the Mesa Venado into a deep tributary arroyo of the Tutuaca, and made a complete cross-section of the Tutuaca cañon to Dolores. Rhyolite flows and ash-beds, and andesite flows and breccias, with an occasional bed of basaltic character, make up the foundation of the series out of which the gorges have been cut. Near the Tutuaca River there is a massive development of the conglomerate "mesa formation," corresponding to the La Brisca formation, which Hill has described from Sonora. These beds are hundreds of feet in thickness in places, but they appear to be local in development—the accumulation of "wash" in the basins of the original surface of the volcanic beds.

Where the trail crosses the Tutuaca the stream is about 125 feet wide and too deep for fording. The mining company at Dolores have built a primitive suspension bridge here for the convenient transfer of their freight. The water for the mill at the Dolores mine is pumped from the Tutuaca to a reservoir 1,700 feet above the river, which gives a head of 200 feet at the concentrator. The mine follows a siliceous vein carrying silver-bearing copper ore, which traverses a heavy bed of diabase. Several quartzose veins project like walls from the acid tuff beds of the region, and are the lodestone which attracted the ancients to the mineral deposits of Dolores and which has induced the modern miner to invest much money here.

Continuing southward from Dolores, we found the country more broken than it was on the east side of the Tutuaca; that is, the dissection of the mesas has continued farther and their tops are less extensive than farther east. At Yepachic, forty miles south of Dolores, we encountered the first agricultural Indian village we had seen since leaving Casas Grandes, a stretch of more than 125 miles in an air-line. The country is practically without permanent population, and it is only at rare intervals that one sees the ranch even of a squatter.

Our next objective point was Cerro Voludo, five miles southwest of Yepachic. The summit of this mountain (7,050 feet) is of densely-indurated rhyolite tuff, and is about at the altitude of the old mesa. Looking westward from Cerro Voludo, one gazes upon a wilderness of cañons and arroyos, with narrow ridges and sharp summits. The view is bounded by the profile of the edge of the great mesa between Trinidad and Mulatos. The topography is relatively old.

A few miles south of Cerro Voludo we leave the water-shed of the Yaqui River and descend 3,500 feet into the V-shaped cañon of the Rio de Mayo, here known as the Moris, which finds its way to the Pacific Ocean south of the mouth of the Yaqui.

In this cañon is to be found the best development that we saw of a dark blue conglomerate, apparently altogether of originally volcanic materials, which is older than the lighter-coloured, higher La Brisca formation. The dark blue conglomerate is massive, hundreds, if not thousands, of feet thick, is tilted at an angle of about 15° toward the southeast, and is separated from the later overlying beds by a long erosion interval, during which there was considerable deformation of the conglomerate. We propose to call this formation the Navosaigame. Water-worn fragments of bluish limestone occurring loose in the river-gravel terraces of the cañon of the Mayo prove the existence farther upstream of marine beds, apparently of Cretaceous age.

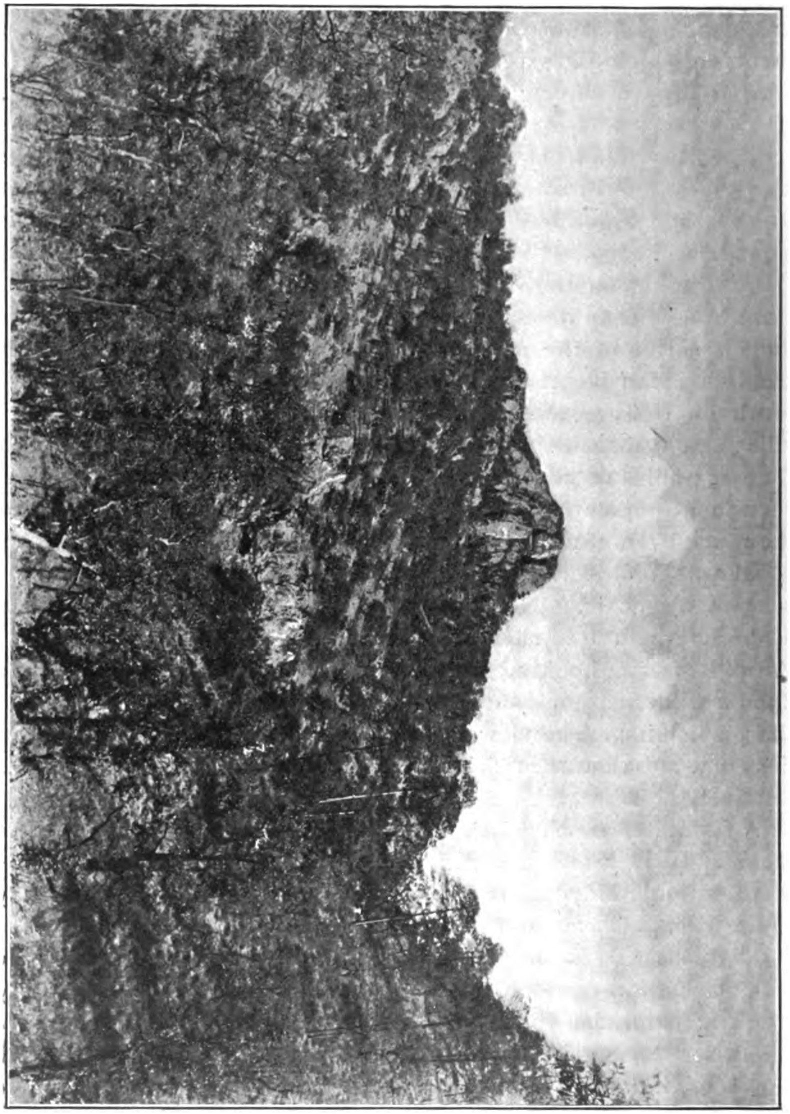

FIG. 4.—CERRO VOLUDO. ALTITUDE, 7,050 FEET A. T.

The trail led out of the Mayo cañon over the Cumbre Potrero into the Arroyo Rosario, which is tributary to the cañon in which Ocampo is located. The region is one of decomposed tuffs and lava beds lying unconformably upon the Navosaigame conglomerate, and the whole series is cut by dikes of all sizes. Ocampo is a celebrated mining camp, better known, perhaps, by its old name of Jesus Maria. From one mine alone, the Santa Juliana, $100,000,000 of silver bullion were taken by its Mexican owners during the last century, but the shaft and lower levels are now flooded. The cañon is so deep, narrow, and crooked that one does not see the town resting in its bottom, 3,000 feet below the rim, until he is fairly on top of it.

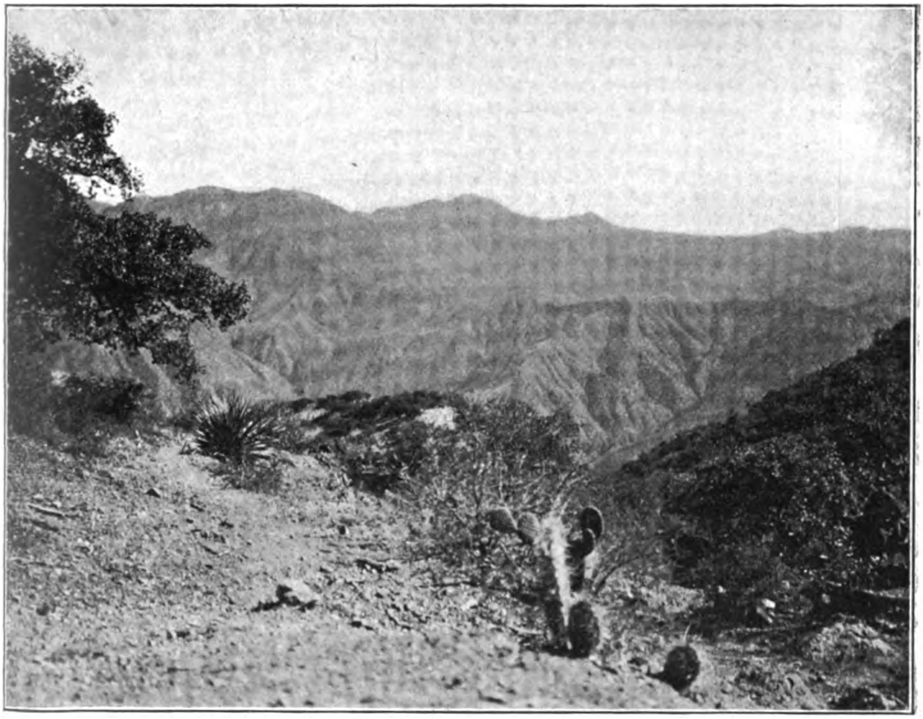

FIG. 5.—CAÑON, RIO DE MAYO (MORIS), AT NAVOSAIGAME. 4,000 FEET DEEP.

The population of Ocampo varies greatly with the prosperity or adversity of the mines. It is said to be about 5,000 now; but it is hard to see where so many people can be stowed away, even in the Mexican fashion. The cabins cling close to the walls of the V-shaped cañon formed by the junction of the two arroyos to make the great cañon. The route out northeastward toward Pinos Altos and Miñaca leads up the eastern branch, "Arroyo San Juan," and 2,400 feet above the camp comes out on the great mesa in the midst of a magnificent forest of giant spruces. At Pinos Altos (from which, by the way, all the "lofty pines" have long since found their way underground as mine timbers) there is a remarkable

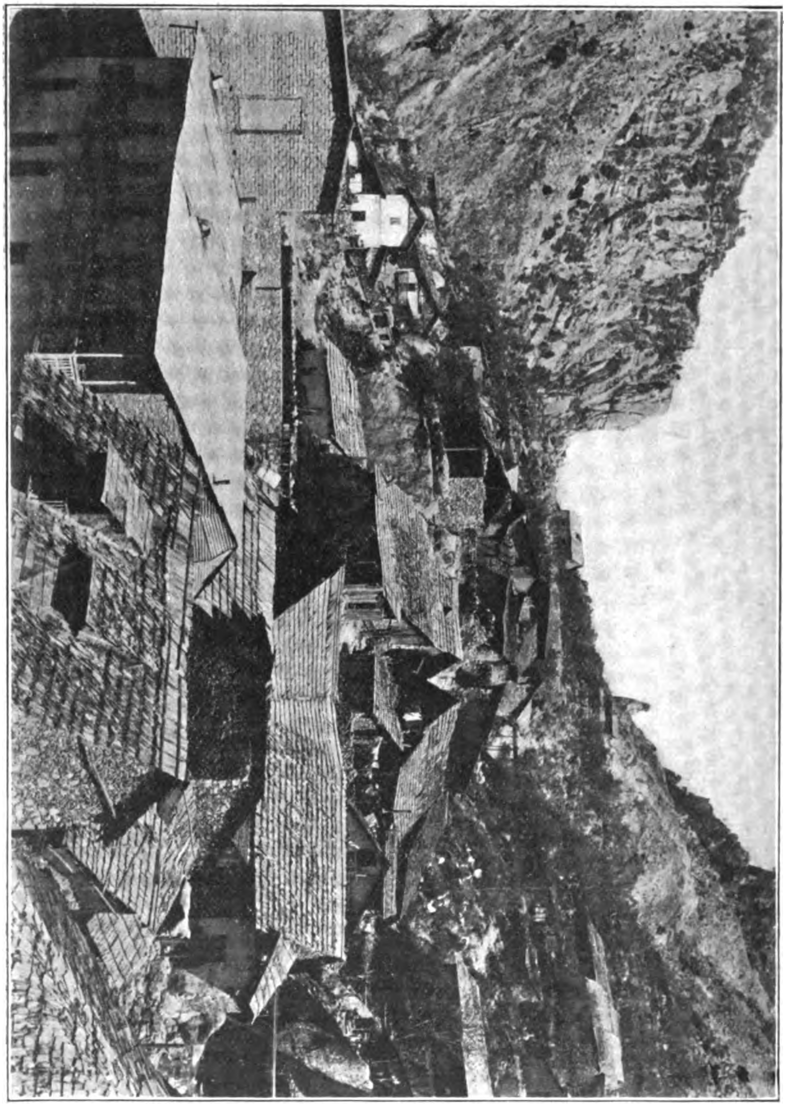

FIG. 6.—OCAMPO (JESUS MARIA). GREAT SILVER CAMP.

series of great quartz veins, which have resisted atmospheric destruction much more successfully than the country rock, and stand out from the mountain sides like gigantic buttresses.

The journey to Miñaca lies over the high mesa at altitudes from 6,900 to 7,300 feet above the sea. The mesa is partly dissected by the headwaters of the Rio de Mayo, the Tutuaca, the Verde, and their tributaries, and north northwest-south southeast ridges rise from 1,000 to 2,000 feet above the general level. The highest points are said to be about 9,000 feet above tide. Extensive flows of basalt are associated with the beds of rhyolite, andesite, and tuffs. Beds of sandstone, apparently old mesa formations, dip toward the northeast at an angle of about 20°.

Miñaca, the present terminus of the Chihuahua and Pacific Railroad, has been established in a beautiful basin-like mesa 7,200 feet above tide, near the base of Miñaca Butte, a mountain of obsidian, which received its name from its having been the last stronghold of General Miñaca, one of the heroes of Mexican history. The railroad is pushing on to the southwest, while toward the northwest a branch track is done as far as Temosachic. From Miñaca to Chihuahua the road traverses a series of bolsons, crosses the "continental divide" at an elevation of about 7,600 feet, and plunges through several picturesque gorges in basaltic and andesitic lava on its way to the bolson (4,633 feet A. T.*) in which the city of Chihuahua is situated.

The route from Chihuahua to El Paso is familiar ground to every traveller in Mexico. One long, narrow bolson succeeds another with gradually lowering altitude until the edge of the mesa on the border of the Rio Grande Valley is reached, when the grades become steeper for the last few miles into Ciudad Juarez. The region is arid and semi-arid, and toward the north one encounters the "bufas" or frog-like monoclinal mountains, the médanos or shifting sand-dunes, and the lagunas, all of which are like the features seen along the Sierra Madre and Pacific Railway.

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* Elevation of the railway station at Chihuahua Mexican Central Railway folder.

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A Tree Fern of Middle Devonian Time

By

EDMUND OTIS HOVEY

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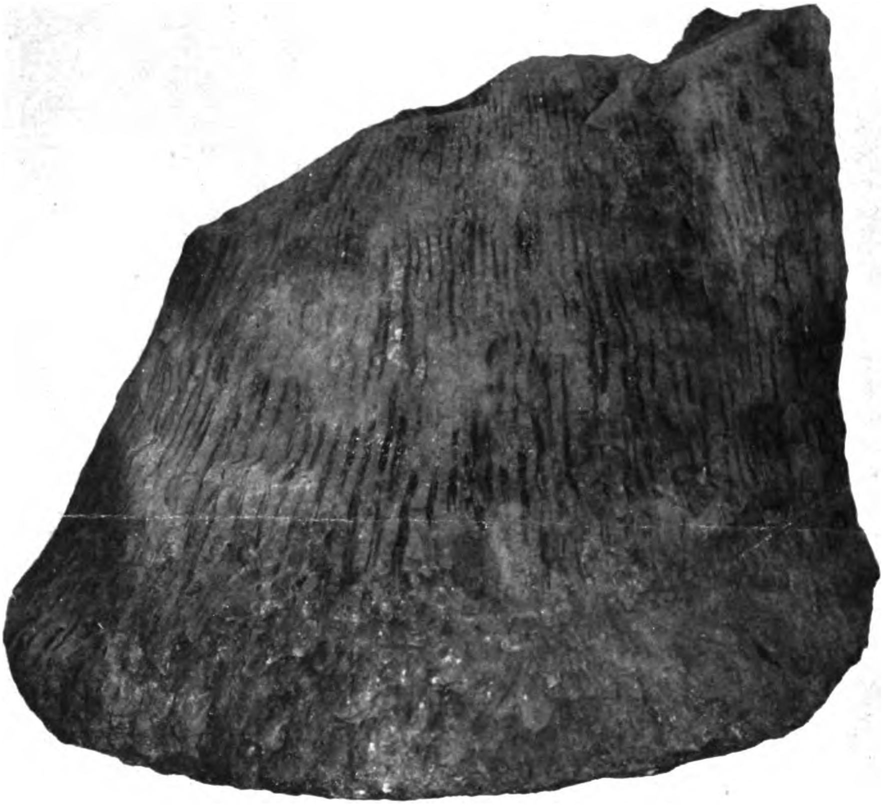

A fossil stump of *Psaronius* recently presented to the American Museum by the New York City Board of Water Supply. *Psaronius* is among the oldest "trees" of which we have evidence, antedating by millions of years the appearance on this earth of the plants of the Coal Period, the great reptiles, and the early mammals, which are so vastly remote when viewed from the standpoint of human experience of time

A TREE FERN OF MIDDLE DEVONIAN TIME

BY

EDMUND OTIS HOVEY*

PLANT life of some kind must have flourished on the continents and islands of very early geological time, but the plants themselves did not contain woody tissue enough for preservation in the fossil state, nor were other conditions favorable for such preservation. It is not until the Hamilton Period of Middle Devonian time that evidences of land vegetation become abundant, and even then the verdure which, it may be assumed, covered the hillsides, disappeared entirely when it died. Lycopods, ferns, horsetails, or scouring rushes, and the like—plants which love the damp spots of the land—are the only forms which have been fossilized, with the result that their remains have come down to us.

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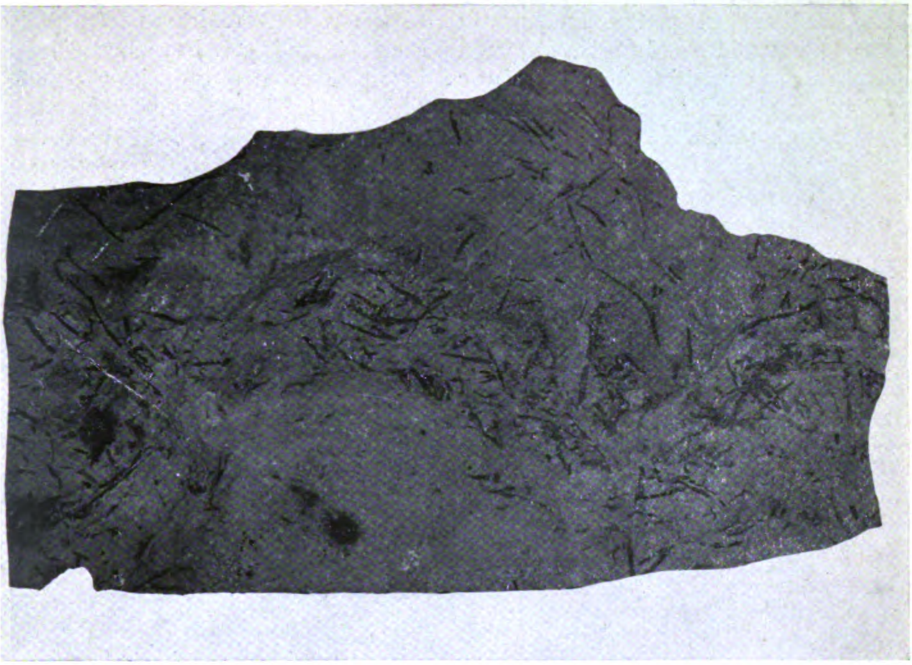
*Curator of Geology and Invertebrate Palæontology.

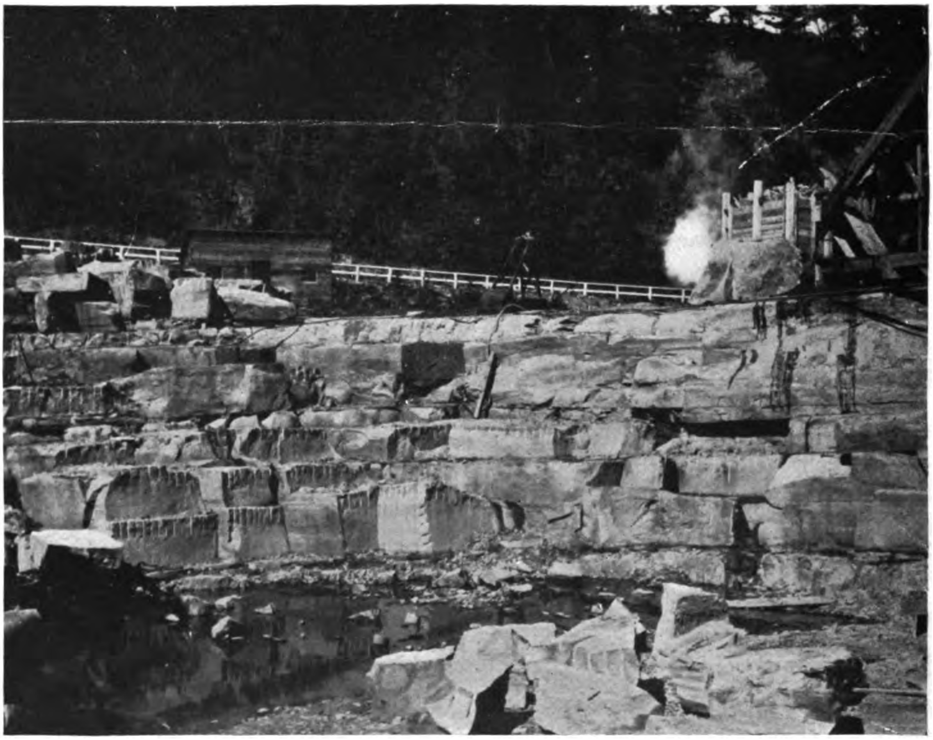


The American Museum is indebted also to the New York City Board of Water Supply for several sizable fragments of rock on which the leaves of the tree fern *Psaronius* left their fossil record to be read and interpreted æons later by man. One of these slabs of rock, with the ribbon-like leaves broadly distributed over its surface, is reproduced herewith

The oldest "trees" known in the world are, accordingly, the gigantic tree ferns of the Hamilton Period of Middle Devonian time. They flourished in the swamps of the regions now known as central New York State and Ohio, as well as elsewhere, and they grew to enormous size, trunks four feet in diameter having been found. The eminent Canadian geologist, Sir J. William Dawson, devoted much study to these forms of plant life, and he gave them the name *Psaronius Erianus*.

In those days of long ago the climate of central New York must have been warmer and more moist than it is at present, and we may picture to ourselves the luxuriance of the old tropical or subtropical forest. Flowers were absent, but the foliage must have been beautiful. The leaves of *Psaronius* were, apparently, ribbon-like in character and rose in a graceful tuft from the short stump. There was no high bole to the tree and it had no branches.

One of the features of the comprehensive plan for using the water resources of the Catskills to furnish an adequate supply of good water to the city of New York is the diversion of the upper portion of Schoharie Creek into the Ashokan Reservoir. In carrying out this project the engineers of the New York City Board of Water Supply are constructing a massive concrete and masonry dam at the little village of Gilboa, Schoharie County, and to secure stone for facing have opened a quarry in the Hamilton sandstone down stream from the site of the dam. In this quarry they have come upon a bed sixty feet below the horizon at which the original Gilboa tree stumps were found, and in this bed they discovered several perfect and nearly perfect stumps of tree ferns resting upon a bed of shale marking the level of the ancient swamp. From this series a stump thirty-two inches in diameter and about two feet high was selected and presented to the American Museum by the New York City Board of Water Supply. This beautiful stump and some of the ribbon-like leaves from the associated sandstone have been installed in the Devonian case in the hall of geology and invertebrate palæontology on the fourth floor of the Museum.



Photograph by E. O. Hovey

Quarry in the Hamilton Sandstone at Gilboa, New York. The stumps of the giant tree fern *Psaronius* were found upon a thin bed of shale exposed at the bottom of the quarry face

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